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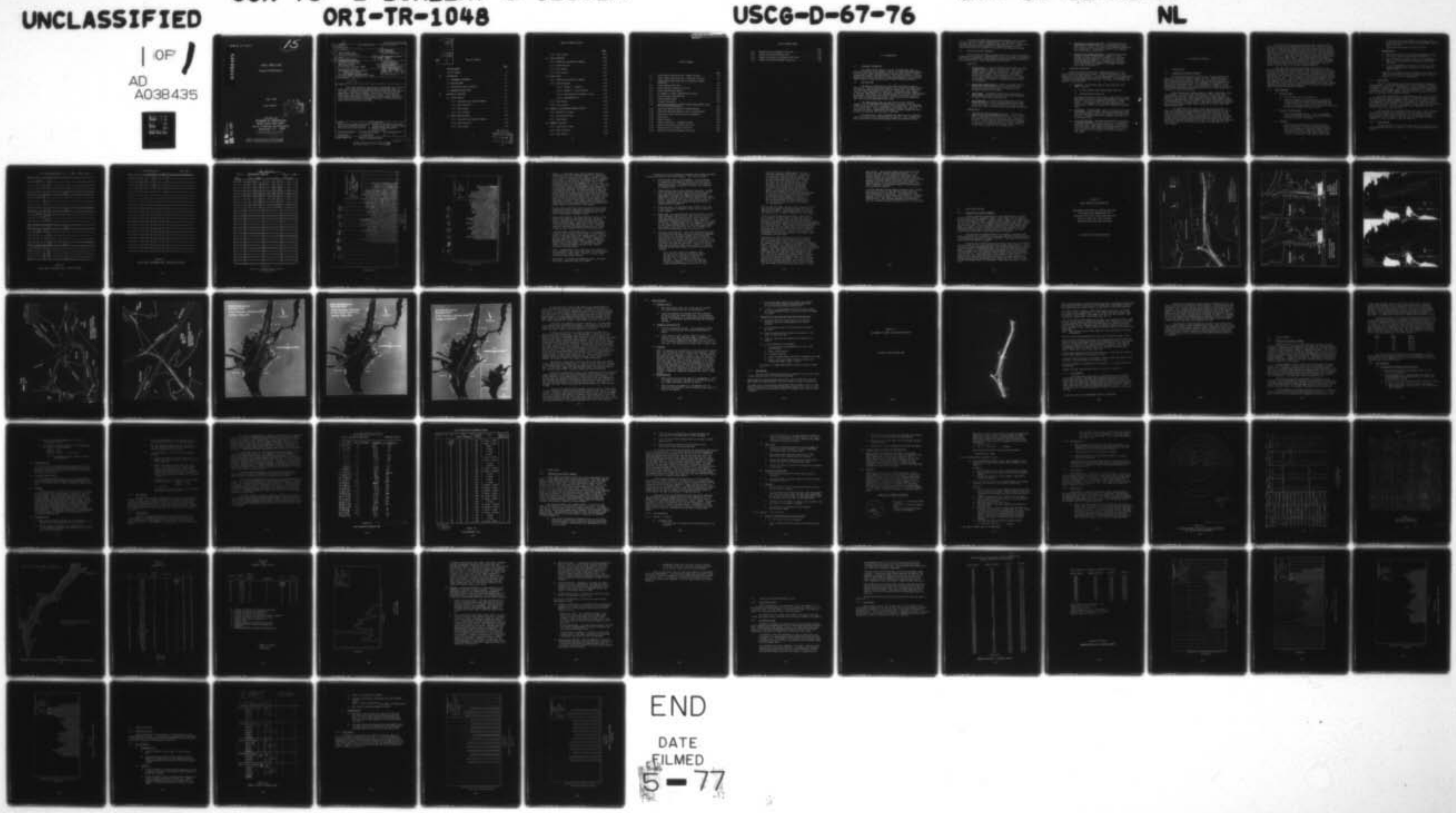

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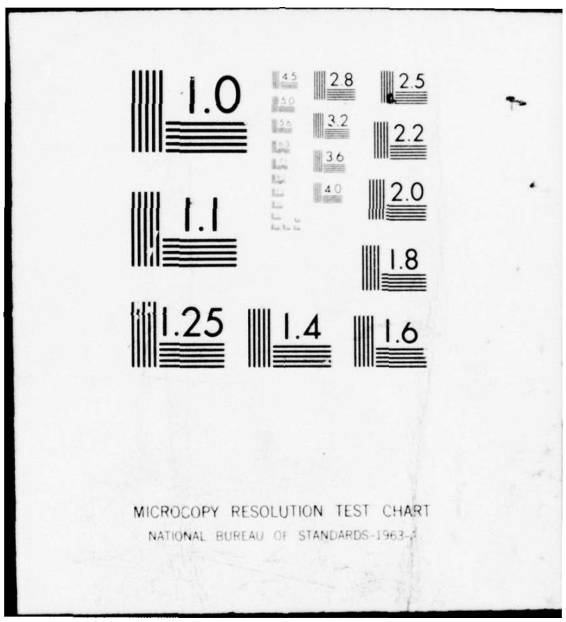
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NATIONAL BUREAU OF STANDARDS-1963-A

REPORT NO. CG - D-67-76

15 B.S.

VESSEL TRAFFIC DATA

EXTRACTION METHODOLOGY

JUNE 1976

FINAL REPORT

PREPARED FOR
DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
OFFICE OF RESEARCH AND DEVELOPMENT
WASHINGTON, D.C. 20590

Technical Report Documentation Page

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16. Abstract

This report presents a description of the methods used to extract vessel traffic data during a 20-month project encompassing seven U.S. port areas. The data was obtained from films of radar PPI's and tapes of communications activity on Channels 13 and 16 of the VHF/FM Maritime Mobile Band. Data analysis obtained the following: Vessel Density; Vessel Route Identification; Vessel Speed; Close Encounter; Message Activity, Channel Utilization, and Channel Efficiency. Discussion of error sources and data display are included.

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1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

This report is the ninth in a series of reports done under U.S. Coast Guard Contract DOT-CG-31446-A, Task 14, "VTS Statistical Data Analysis". The first eight reports presented data concerning vessel traffic in seven selected port areas in the United States. This report describes the various methods used to extract the data in a step-by-step format; it also contains some discussion of data display and error factors affecting the data.

1.2 RAW DATA FORM

The data was supplied in raw form (films and tapes) by the U.S. Coast Guard. There are two general types of data—radar and communications. The radar data are extracted from 16 mm color movie film. Each frame consists of a time lapse photo of a radar PPI. The exposure time is keyed by the radar sweep making a full 360 degree rotation on the CRT, (approximately 4½ seconds). Julian date; time in hours, minutes, and seconds (using a 24 hour clock); a range scale indication; a visibility code; and benchmarks (all using LEDS) are presented on each frame.

The communications data are taken from C120 tape cassettes. Channel 13 of the VHF/FM Maritime Mobile Band is recorded on one track and Channel 16 plus a time code is recorded on the second track. This time code is in IRIG B format. If no transmissions are available from Channel 16 then the time code is imposed every one second. Whenever Channel 16 transmissions are received, the time code is inhibited.

The same clock is used to generate the time code on the communications tapes and the time illuminated on the radar PPI. Thus a common time base is available for correlation between radar and communications data.

The radar and communications receiving equipment are all located on a U.S. Coast Guard owned and operated van. For each harbor area of interest, the van is usually situated at more than one site. At each site, the radar-observed vessel movements are filmed and Channel 13 and 16 radio transmissions are recorded for a period of approximately one week.

1.3 DEFINITION OF DATA EXTRACTED

From the radar and radio coverage at each site, certain quantitative information was extracted. Specific definitions of the types of information desired were established, and the methods of obtaining the data were derived from the definitions. These definitions are as follows:

RADAR DATA

- Vessel Density - A count of vessels present within the radar coverage, taken at regular time intervals. The interval between counts is chosen to be equal to or less than the average vessel transit time of the site. The vessels counted are classified in types appropriate to the site, such as large, medium, small, tug with tow, etc. The data is displayed in the form of a histogram with time of day as the abscissa.

- Vessel Route Identification - A map of the radar site displaying the routes used by vessels transiting the area. Vessels are identified by type, and significant land and water features are indicated.

- Vessel Speed - A histogram displaying the distribution of sample speeds recorded at the site, and a table presenting the speed figures with associated data.

- Close Encounter - A count of vessel encounters and close encounters observed, using close encounter criteria based on the radar scale. The close encounter figures are presented in a table, along with certain qualifying information.

COMMUNICATIONS

- Communications Channel Message Activity - A count of the number of messages transmitted on channel 13 of the VHF/FM Maritime Mobile Band, as a function of time. The count is extracted from the tapes by an automated system developed by the U.S. Coast Guard R&D Center. The data is presented in the form of a histogram with message counts totaled in fifteen-minute intervals over a 24-hour period.

- Communications Channel Utilization - The percentage of time that Channel 13 is utilized, i.e., the percentage of time that squelch is broken. This data is also derived automatically, and is presented in fifteen-minute periods, on a histogram, with time of day as the abscissa.

- Communications Channel Efficiency - The percentage of valid messages to total transmissions on Channel 13. Valid messages are those judged to be conforming to the Bridge-to-Bridge Radiotelephone Act. The counts for valid and total messages are taken within fifteen-minute intervals, and the percentages are displayed in histogram form with time of day as the abscissa.

1.4 EQUIPMENT DESCRIPTIONS

There are three major pieces of equipment necessary to do the data extraction described in this report. They are a projector, a tape player, and a time code translator. In each case, however, certain specialized features are also necessary for accuracy and efficiency. The equipment used in obtaining the data presented in the eight "VTS Statistical Data Analysis" reports is described below.

- Projector - Two different types of 16 mm projectors were used. They are:

  1) L-W Photo Optical Data Analyzer Model 224A MKII

  2) Lafayette Analyzer Model 100

  Both models have remote control with variable speed in forward and reverse, as well as a single frame advance in forward and reverse. The L-W uses a 1000 watt lamp and has a frame counter. The Lafayette uses a 750 watt lamp and has no frame counter, however, it proved more reliable for prolonged usage.

- Tape Player - The tape player used is a Technics Dolby System by Panasonic, model RS-27165, stereo tape recorder and player with separate channel output level controls and channel level monitors. Headphones were used for maximum protection from environmental noise.

- Time Code Translator - The time code translator is necessary to decode and display the time code which is recorded on the Channel 16 track of the communications tapes. The Datatron Model 3700 Serial Remote Display accepts and decodes serial time code signals, and displays the decoded time on a front panel readout in Julian date and time in hours, minutes, and seconds.

2.0 METHODS OF EXTRACTION

2.1 VESSEL DENSITY

2.1.1 Preparation and General Comments

The vessel density counts should be the first data extracted for each site. There are a number of reasons for this. When taking vessel density counts, the entire week of radar film is observed, resulting in both a familiarity with the site, and a knowledge of any exceptional occurances during the coverage period. This information is important to the extraction of other data. Also, once vessel density is known, it can be used in making related data extraction decisions such as what period should be covered in route identification.

Before taking vessel density counts, a number of preliminary steps are necessary. The first is site identification. On the radar film, locate the radar position (center of scope) and the general features of the site — land and water. Then compare the film to a well detailed chart of the area (National Ocean Survey charts are usually sufficient) to identify all fixed features of the radar return. These should include minor features such as buoys, bridges, islands, docks and warves, as well as major land masses and waterways.

The second preliminary step is vessel type classification. As there is at present no way to standardize size classification from site to site, the classification scheme is based on the relative sizes, and the clarity of distinction of these sizes, at each site. Therefore, traffic at the site must be observed and a decision made as to what types are appropriate to the site and how distinctions between the types are to be made. One rule of thumb can be applied to all sites. If a tug with tow is observed at the site, the size of the tug can be used as the upper bound for the small category.

The third step is to determine the appropriate sampling interval. There are two types of considerations relative to this. The first is that the interval should not be greater than the average vessel transit time for the site. To determine the average transit time, simply clock a representative sample of vessels as they enter and leave the site, using the time displayed on the film. The average of these times can be used as average transit time. Once this is known, the second consideration comes into play, which is the final form of data display. Since vessel density is presented in histogram form with time of day as abscissa, fractions of hours, with appropriate intervals beginning or ending on the hour, are desirable. For most sites and radar scales, 15-minute intervals are appropriate. Sites of smaller areas may require 10- or even 15-minute intervals.

Once these three steps have been taken, there remain only the decisions regarding the practical aspects of how the counting is to be done. These are, how many people are required to do the counting, and can the site be counted as a whole or should it be segmented. Considerations are traffic density and traffic patterns at the site. In general, heavy traffic requires two data takers, and if traffic patterns are also complex, segmenting of the site is also required. Two rules should be observed when breaking a site into segments for the vessel count. First, each segment must be so chosen that the vessel traffic within is comfortably observed by one person. Second, land masses and other stationary images on the film should be incorporated wherever possible when developing segments.

2.1.2 Data Extraction

- Projector Setup

  1) Reel the radar film on the projector.

  2) Place the projector at a distance from the projection surface, so that the vessels are distinguishable, and so the projection is at right angles to the projection surface. The projector should not be moved during the count of the site if sector divisions are used.

- Projection Surface Setup

  Trace the background features. This is recommended when sector divisions are used, or whenever stationary features are desired to be marked.

- Procedure

  Run the projector forward to the first count time. Reverse film until it is about 5 minutes before the time to be recorded, then run film forward to desired time and count vessels. Repeat this process until satisfied that all vessels have been counted. Note: the count is taken only at the express frame chosen

as the count time. The process of running the film up to that time is to permit the distinction between stationary and moving images.

Repeat the above process for each count time.

- Recommendations

1) When sector divisions are used the recommended procedure is to count vessels present, section by section.

2) When two people are needed to count, it is recommended that one run the projector and the other person count and record.

3) It is also recommended that counts of vessels at anchor be made separately when the density of the vessels is generally high.

Examples of the recording forms for sector and non-sector divisions and for counting at anchors separately are included in Figures 2.1, 2.2, and 2.3, respectively.

2.1.3 Data Display

After all vessel counts are recorded and totaled, the numbers are transferred to a pre-printed intermediate or "draft" histogram, as shown in the example in Figure 2.4 . The abscissa is time of day and the ordinate is number of ships present. The value of the ordinate units is determined by the peak value of ships present. Abscissa hours are divided into units equal to the length of the sampling interval.

Each vessel density count is represented by a bar, the base of which is centered on the time the count was taken. The height of the bar equals the total number of vessels present at the count time. The bar is divided into segments of length proportional to the numbers of the various vessel types contributing to the total. Each segment is then number-coded to identify the appropriate type. The key to the type code is assigned at the top. Finally, location and date are filled in.

With the data thus transferred to the draft plot, a final histogram can be easily prepared on a pre-printed "final" histogram, by tracing in ink the outline and divisions of the bars, filling the bars and vessel type key with a graphic design code, and typing in the remaining data. An example of a final histogram is given in Figure 2.5 .

2.1.4 Error Sources

Factors inherent in this type of vessel density determination which could cause reported counts of density to differ from actual density are as follows:

Site Governors Island Day 133 Page 1

Section	Time		Large	Small	Tug	Dredge	Hitch	Total	Time Lapses / Problems
1	16	15	1	6					
2			1	4					
3			4	2					
4				1					
Totals			6	13				19	
1	16	30	5	1					
2			2	4					
3			2	3					
4									
Totals			9	8				17	
1	16	45	3	6					
2			—	—					
3			3	3					
4				1					
Totals			6	10				16	
1	17	00	2	4					
2				5					
3			4	5					
4				1					
Totals			6	15				21	
1	17	15	4	1					
2			1	3					
3			1	2					
4			0	0					
Totals			6	6				12	

Figure 2.1

VESSEL DENSITY RECORDING FORM - SECTOR DIVISIONS

Site - Governors Island Page 1

Day	Time	Large	Medium	Small	Tug	At Anc	Total	Time Lapses / Problems
133	16 15	6		13			19	
	16 30	9		8			17	
	16 45	6		10			16	
	17 00	6		15			21	
	17 15	6		6			12	

Figure 2.2

VESSEL DENSITY RECORDING FORM - NON-SECTOR DIVISIONS

At Anchor

Site - Governors Island   Page 1

Day	Time Start	Time End	Number
133	06 06	07 40 58	6
	07 41 00	09 59 05	7
	09 59 09	10 05 08	6
	10 05 12	11 42 32	5
	11 42 36	12 38 39	6
	12 38 43	12 39 56	5
	12 40 00	12 54 54	6
	12 54 58	16 14 34	5
	16 14 39	16 18 22	4
	16 18 26	end of film	5

Figure 2.3

VESSEL DENSITY RECORDING FORM FOR COUNTING AT ANCHOR SEPARATELY

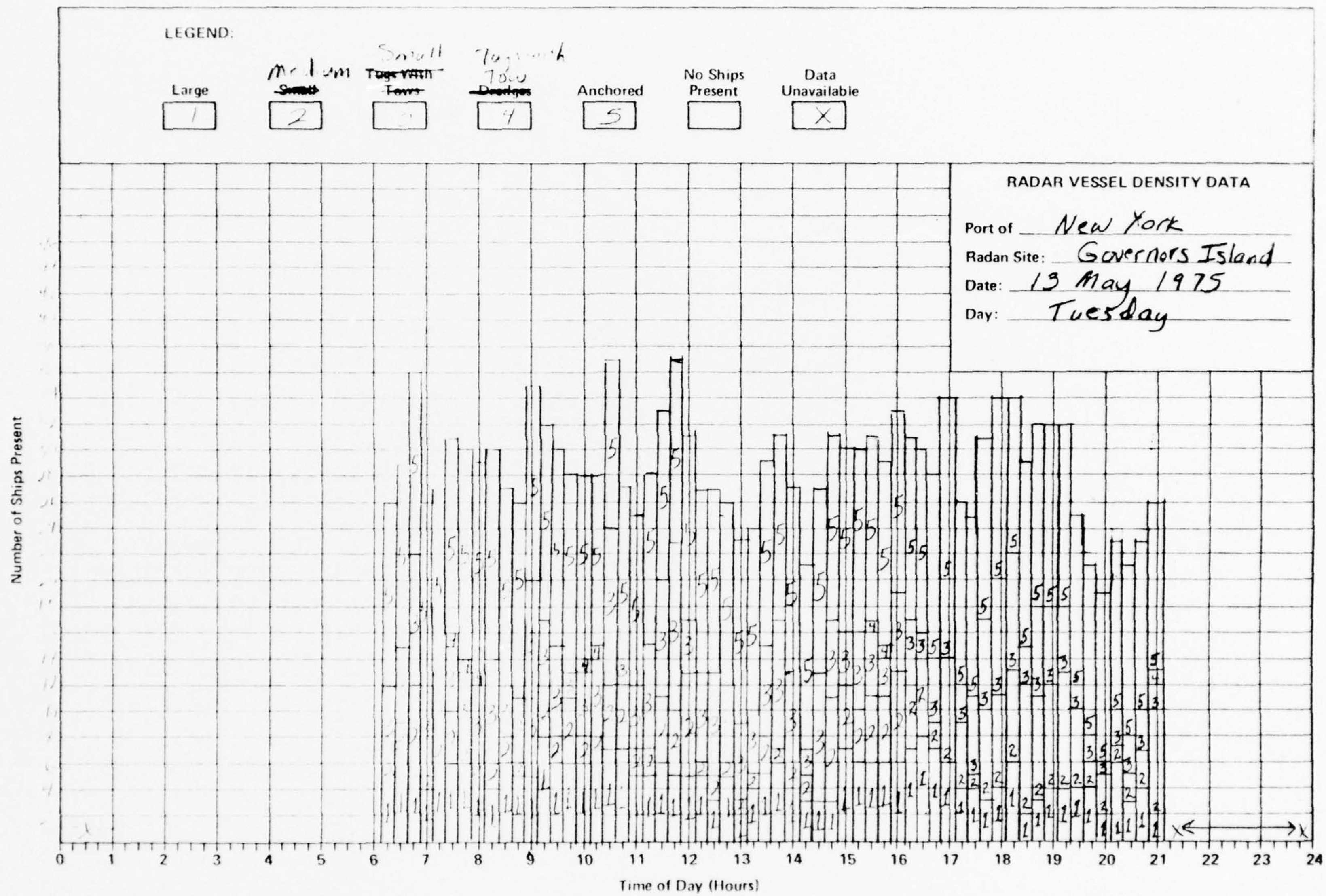


Figure 2.4

VESSEL DENSITY DRAFT PLOT

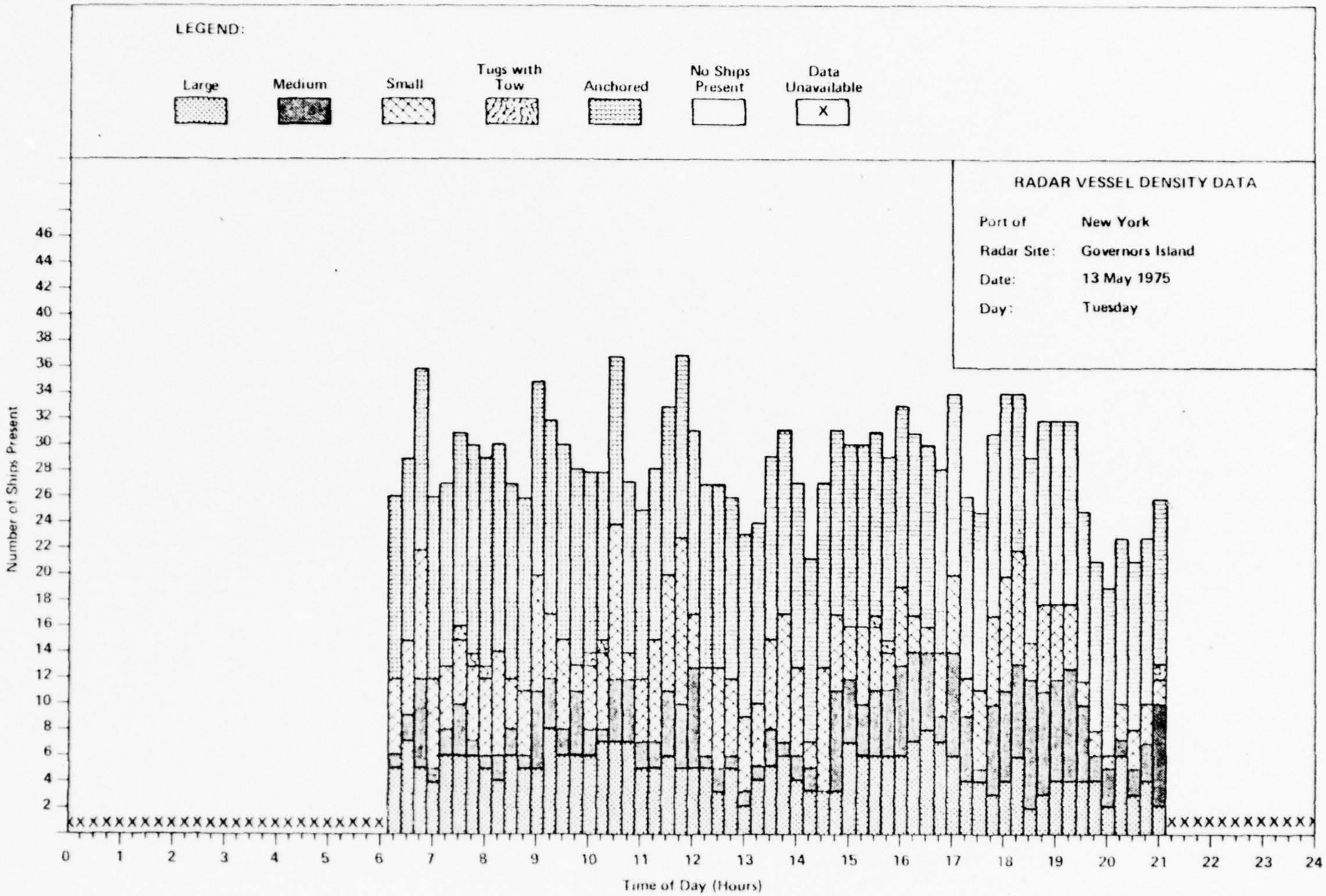


Figure 2.5

VESSEL DENSITY HISTOGRAM, FINAL FORM

1. Shadows - at some radar sites, certain physical features cause shadows, or areas from which there is no radar return. It is not possible to be certain of what is present in these shadow areas. In some cases, the shadowed area is considered to be outside of the site area, and vessels are no longer counted once they enter the shadowed area. This is true only when the area is on the periphery of the site. An example of this type of shadow is the Portsmouth site (Chesapeake Bay Area Report) where the southernmost segment of the river is blocked from the radar. In cases where the shadowed area falls entirely within the site area, an attempt to include vessels within the shadowed area is made by observing vessels as they enter and leave the shadowed area. An example of this type of condition occured at Eatons Neck Point where a boathouse near the radar location caused a narrow shadow band stretching to the west. (The shadow areas at Portsmouth and Eatons Neck Point are displayed on their route identification charts, given in section 2.2.1 of this report).

   At sites where vessels pass near the radar location, moving shadows are created by the vessels themselves. While these moving shadows are an annoyance in vessel counting, they are of no consequence in terms of errors.

2. Bright Center Returns - the high intensity of return at the center of the radar picture creates an area, varying in size at different times, in which individual ship returns cannot be distinguished. Areas such as these are treated in the same way as shadow areas within a site - observing vessels as they enter and leave the area so as to include in density counts vessels within the bright center area.

3. Side Lobe Effects and Multiple Returns - it is possible for a radar to pick up returns from a target in its main beam as well as the side lobes of the antenna pattern. This will result in two echoes on the PPI, separated in angle but at the same range, for a single vessel. Also, propagation anomolies can cause multiple echoes to appear at the same bearing from a single vessel. In performing the vessel counts, an effort was made to exclude "extra" targets resulting from these effects.

4. Noise - although noise in the radar return would generally not be expected to move like a ship return, it could possibly interfere with a vessel count. That is, rain and clutter return could mask certain targets.

5. Miscounting - although every attempt was made to eliminate this factor, human error must be included.

Assigning the count to categories introduces factors which may cause a return to be counted in the wrong category. Such factors include:

1. Differing Return Due to Ship Movements - as a ship moves, it changes its relationship to the radar location by both distance and aspect. This causes one ship to give varying returns which could be counted in different size categories at different times.

2. Differing Return Due to Radar Intensity Variations - at many sites, the intensity of the radar return can be observed to vary from period to period. Whether caused by internal (equipment) or external (environmental) considerations, the effect is to vary the size of all site returns as the intensity varies. Thus vessels of a given size could be counted in one size category during a period of high intensity and in another during low intensity.

3. Borderline Cases - an individual return, which is very near to the size at which categories divide, could be counted in either category.

4. Radar Range - at sites where the range of the radar is set for longer distances (Scales 5 and 6, with radii of 6 and 12 nm) some small and/or low vessels can pass out of the radar's range before passing out of the site. These vessels are included in the density counts only so long as they are visible to the radar. (Representation of this phenomenon is available on route identification charts for such sites, where vessel paths appear to end within the site. For an example, see the chart for Eatons Neck Point in Section 2.2.1).

5. Behavioral Classification - vessel type classifications based on distinctions other than size rely on analytical judgement. The validity of such analysis depends on the information available for the site, both from the radar film and from other sources. For example, the percent of all tugs with tow included in the count for this category at a given site varies with radar scale and local practices. At New York Harbor, where data was taken at radar scale 5 (radius of 3 nm) the following criteria were stated for counting the tug with tow category:

   "For a tug with a tow to be counted as such, the tow must be following at distances ranging from 90 yards to 1,000 yards as observed on the radar film. Two types of towing are possible. First, the tug may tie up alongside a barge (for example). For this case, the radar cannot distinguish between the two and the return

would be counted as a single vessel. For the case where the barge (for example) is tied to the tug using stern lines from the tug, the ability to distinguish a tug with tow will depend on the distance between the tug and the tow. If they are close, the radar returns may merge causing the total return to look like a single vessel. Conversely, the distance may be large enough to mistake the tug with tow for two separate vessels. If the returns merge, nothing can be done to discriminate from a single vessel. If the returns are separate, the mistaken interpretation of two vessels can, in most cases, be eliminated by observing relative speeds and distance. If the relative distance appeared constant while the two returns moved in a manner characteristic of a tug and tow, the two returns were counted as a tug with tow."

Thus, at New York Harbor, the only vessels included in the tugs with tow category are those tugs which pull tows at the required distance. Tugs pushing barges, or with tows tied alongside, are virtually eliminated from the category.

The Port of New Orleans data was taken at radar scale 3 (1.5 nm radius) for most sites. In this area, almost all barge traffic is in the tug pushing barge configuration. Yet, due to the change in scale, this type of tug could usually be distinguished quite clearly, with the tug and barges appearing as a string of pearls. The distinction was good enough to allow for small (with one barge) and large (with more than one barge) tug with tow classifications to be included on route identification charts. At sites such as this, the percentage of tugs with tow included in the category count is expected to be quite high.

Other behavioral type classifications depend even more heavily on extra-radar site information. For example, if a ship would come to anchor in an area where no ship was expected to anchor, it would be considered as a possible dredge. Conversely, if a dredge would appear in an anchorage area, it would most likely be considered to be in the "at-anchor" category. Typically, dredges sortie to a specific area at moderate speed. When they reach the dredging area, they will either anchor or move very slowly through the area. Thus, they can be mistaken for anchored vessels. However, this type of error was minimized through a knowledge of certain characteristics of dredges. First of all, dredges usually give a rather large radar return because they may have one or more barges alongside. Also, tugs will rendezvous with dredges to retrieve loaded barges and to deliver

empty barges. Thus, certain dredge radar returns are large returns with small targets merging and emerging. Yet, at the Fort Schuyler site of the New York Harbor area, such "dredge" behavior was associated with stake boats, while at Texas City Dike site (Houston area) many returns which initially appeared as anchored vessels were found to be stationary features such as oil rigs and secured dredging pipes. This type of behavioral discrimination, based on site information, was used whenever possible.

It can be concluded from the above discussion of Error Sources that errors can occur in both the total vessel count and the categorization of the vessels. The magnitude of this error is difficult to assess analytically since it is primarily dependent on the proficiency of the person deriving the data from the films. Thus, the best approach to assessing the error is to compare the data with other data if it is available.

2.2 ROUTE IDENTIFICATION

2.2.1 Preparation and General Comments

The most significant preparation for route identification is accomplished once an initial judgement is made — that of what is to be shown on the route identification chart. In general, what is shown is the routes taken by the various types of vessels transiting the site during a peak traffic period. For most sites, therefore, this judgement involves simply deciding what is the peak traffic period. This can be done by consulting the vessel density data. There are features of traffic patterns at certain sites, however, which are distinctive and interesting, but which might not emerge clearly on a route identification chart made up soley under the above criterion.

Since the type of phenomenon which is of interest is precisely that which is particular to a given site, no rule can be derived to define the class of phenomena which requires this special attention. The nature of these special cases can best be depicted by example.

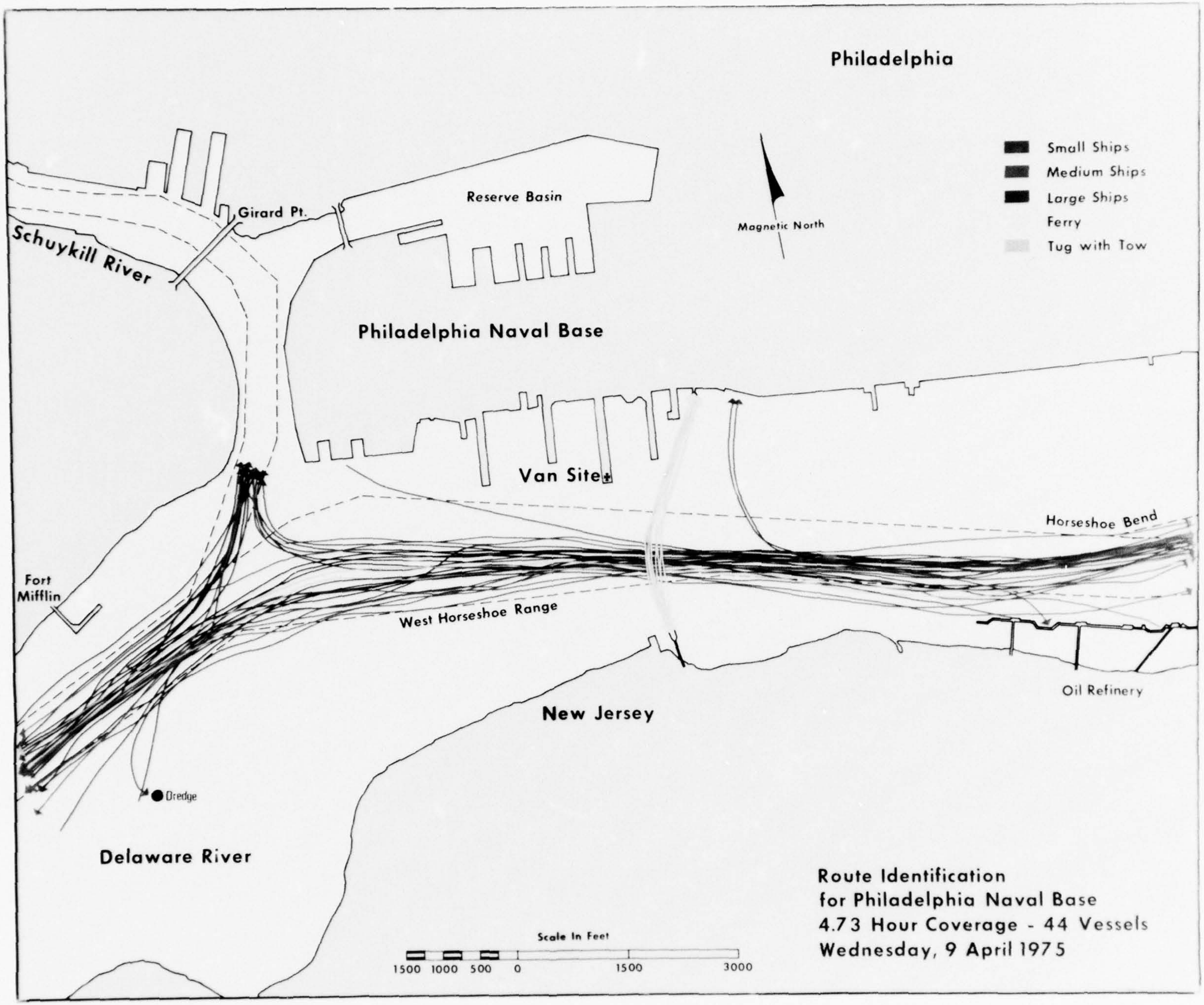
A typical route identification chart displays the routes of all vessels transiting the site for a given period of time (a peak traffic period). Such is the case for the Philadelphia Naval Base site from the Delaware Bay Area report, shown in Figure 2.6. A modified version of this type of route identification chart was prepared for the Elizabeth River Portsmouth site of the Chesapeake Bay Area report. It was observed that traffic patterns here were unusual for a river site in that a large proportion of the traffic was local traffic. To emphasize this, the route identification was done for a peak traffic period, but two separate charts were produced, one showing the local traffic and one showing the through traffic for the period. These charts are shown in Figure 2.6

Figure 2.6

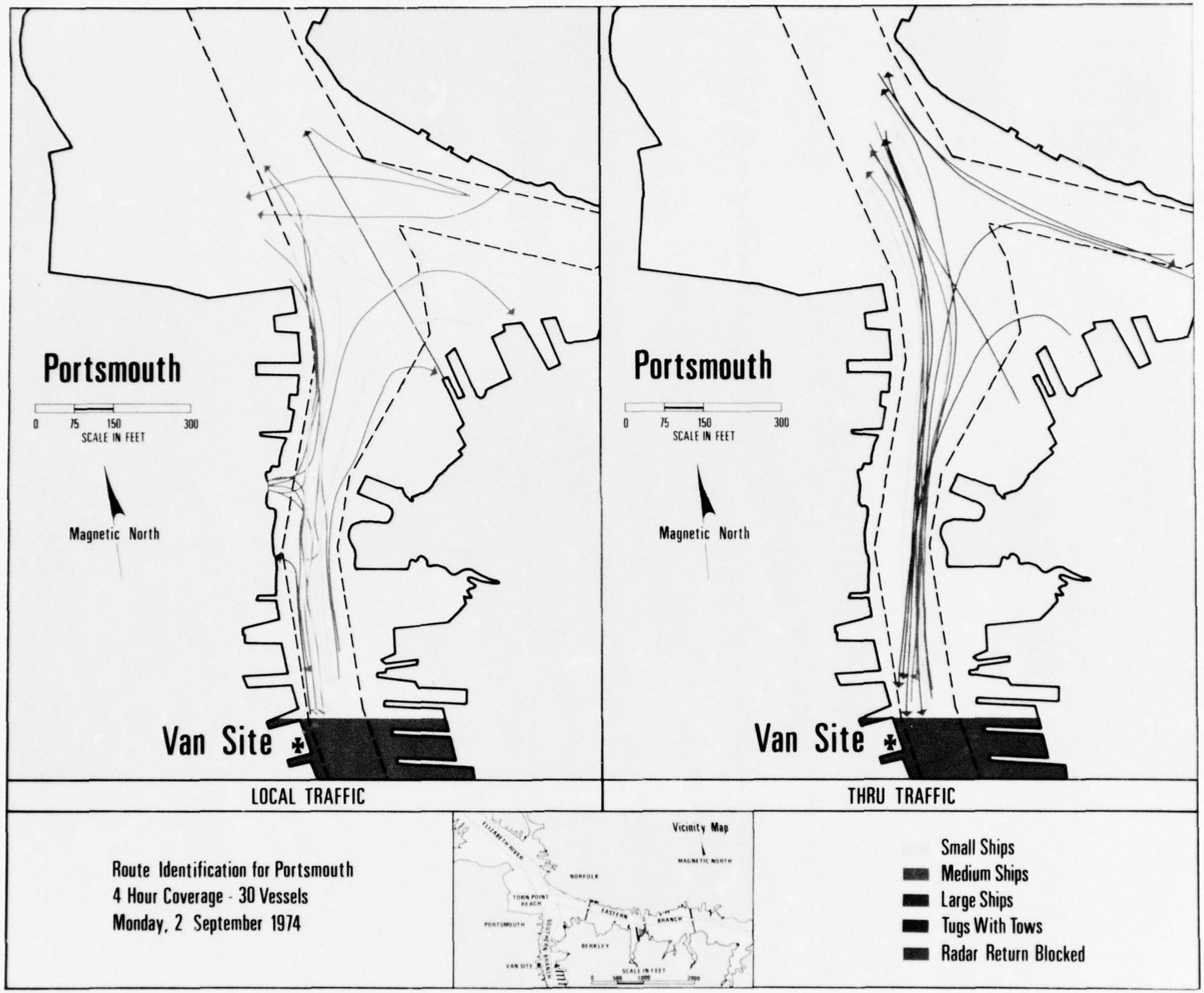
ROUTE IDENTIFICATION CHARTS FOR:

Philadelphia Naval Base Site, Delaware Bay Area
Portsmouth Site, Chesapeake Bay Area
Eatons Neck Point Site, Long Island Sound Area
Texas City Dike Site, Port of Houston
Governors Island Site, New York Harbor

are given in the next eight pages



Route Identification
for Philadelphia Naval Base
4.73 Hour Coverage - 44 Vessels
Wednesday, 9 April 1975



Route Identification for Portsmouth
4 Hour Coverage - 30 Vessels
Monday, 2 September 1974

Plate I

Route Identification for
Eatons Neck Point
8 Hour Coverage
0000 to 0800 Hours — 14 Vessels
Friday, 18 April 1975

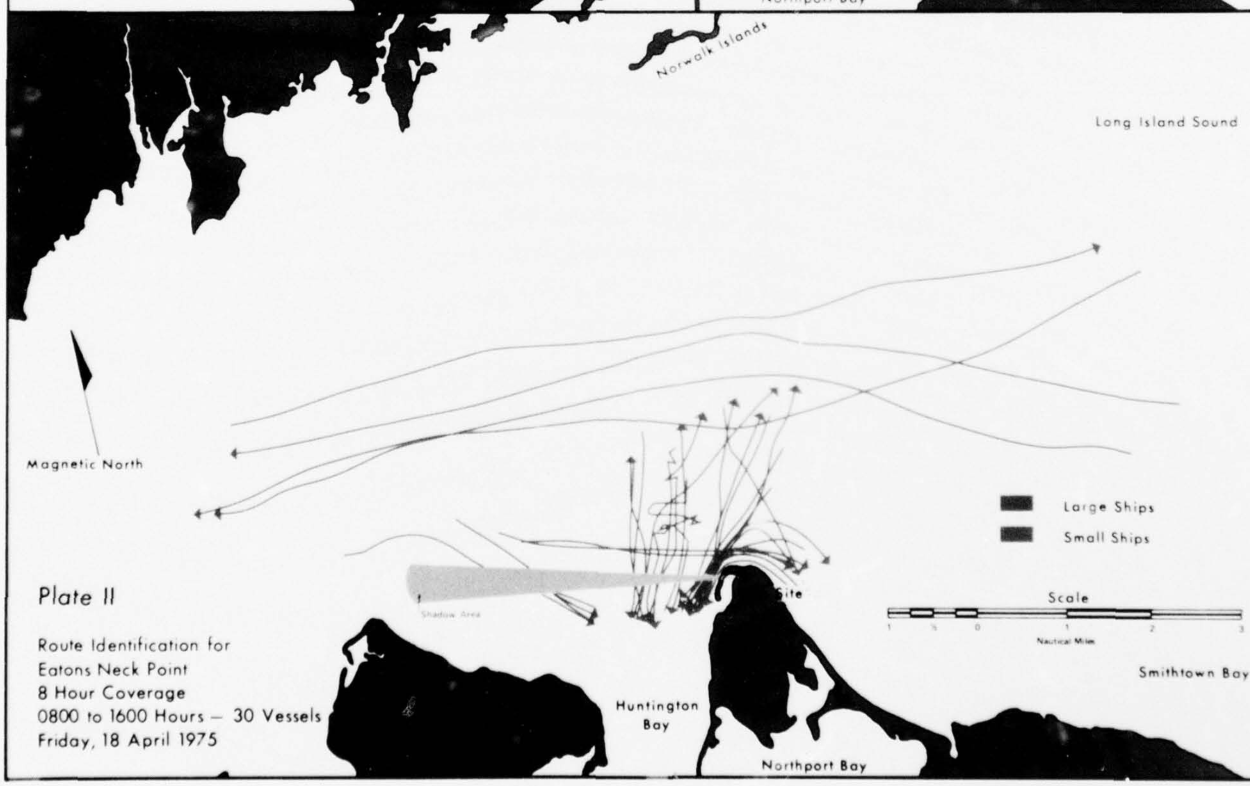
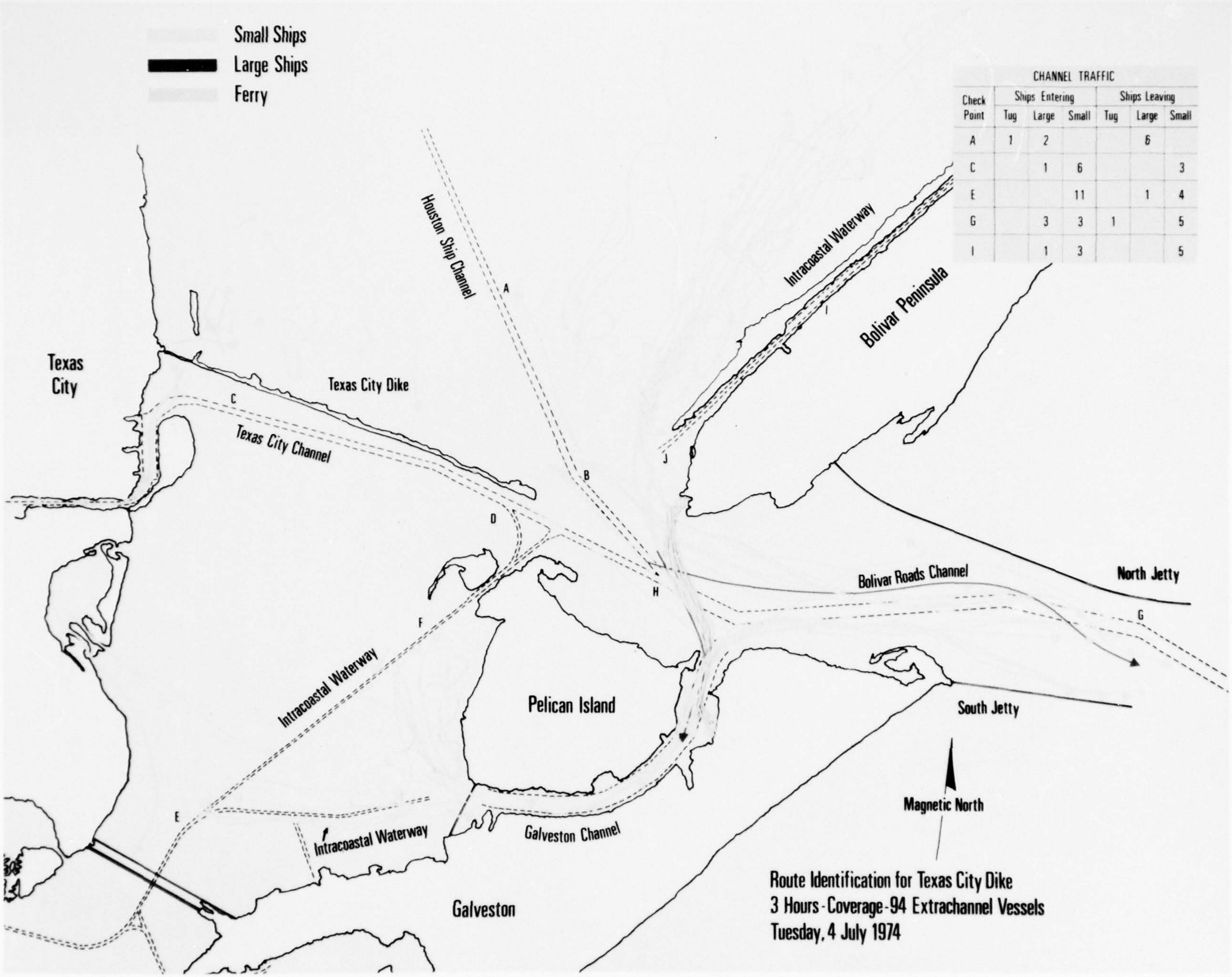


Plate II

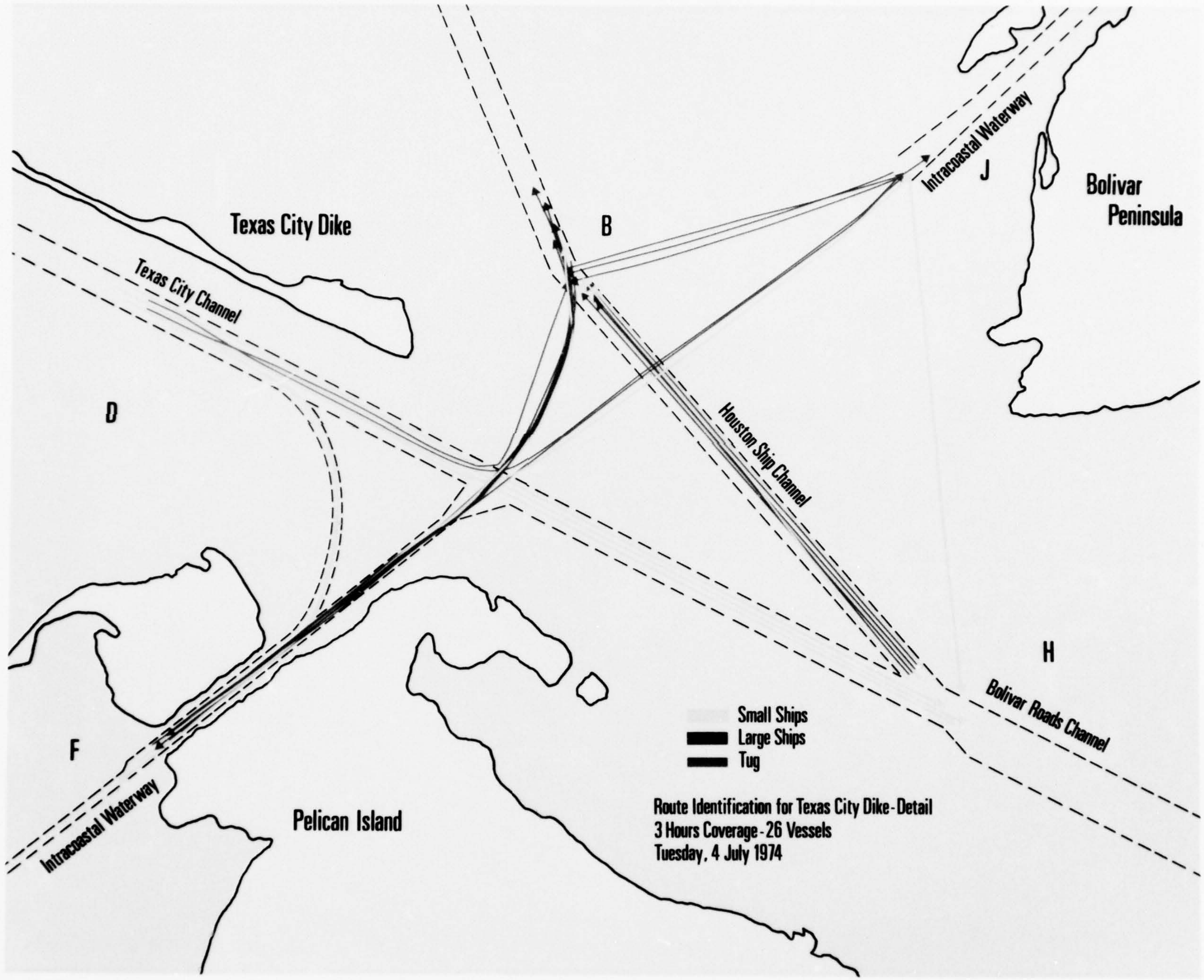
Route Identification for
Eatons Neck Point
8 Hour Coverage
0800 to 1600 Hours — 30 Vessels
Friday, 18 April 1975

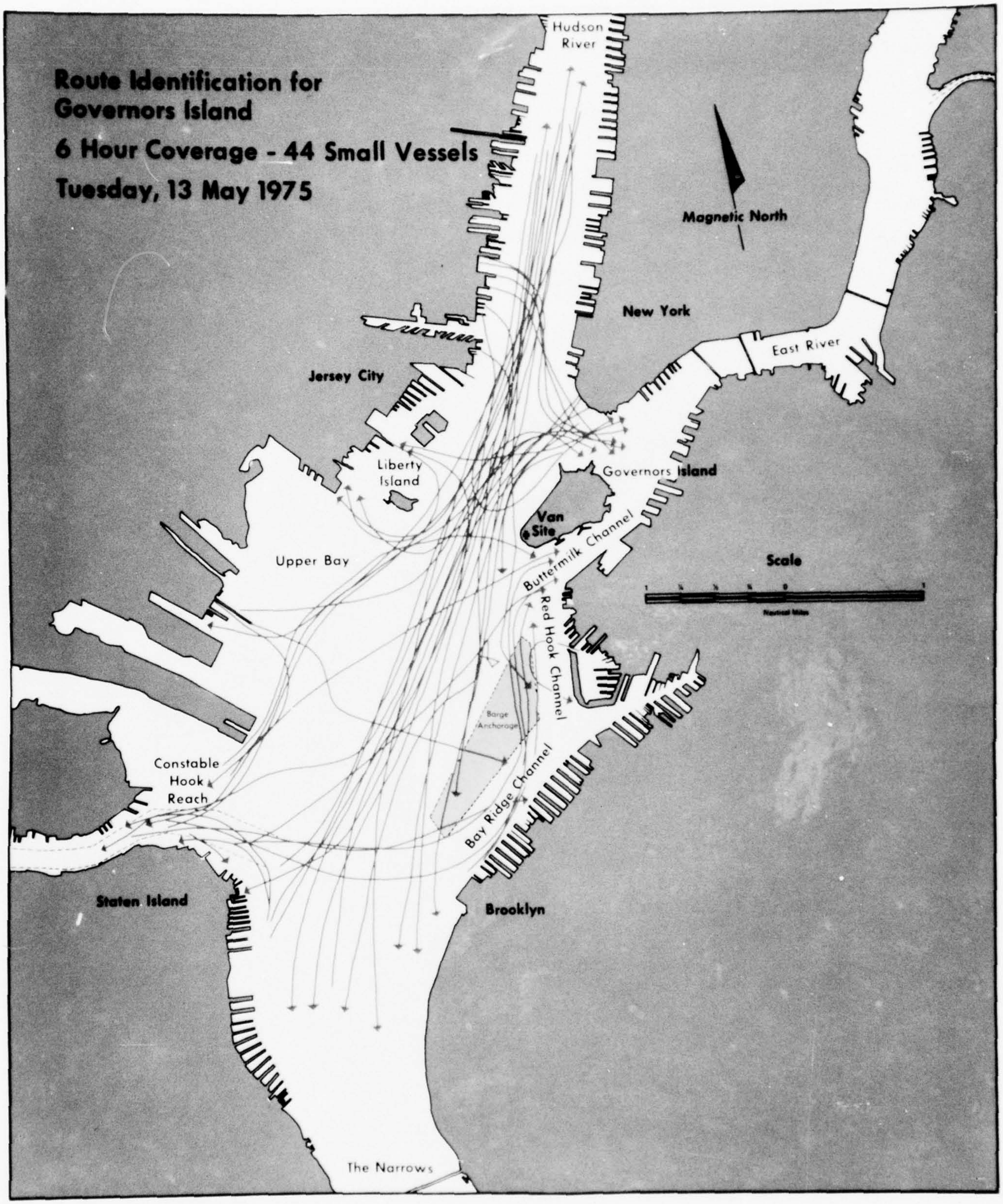


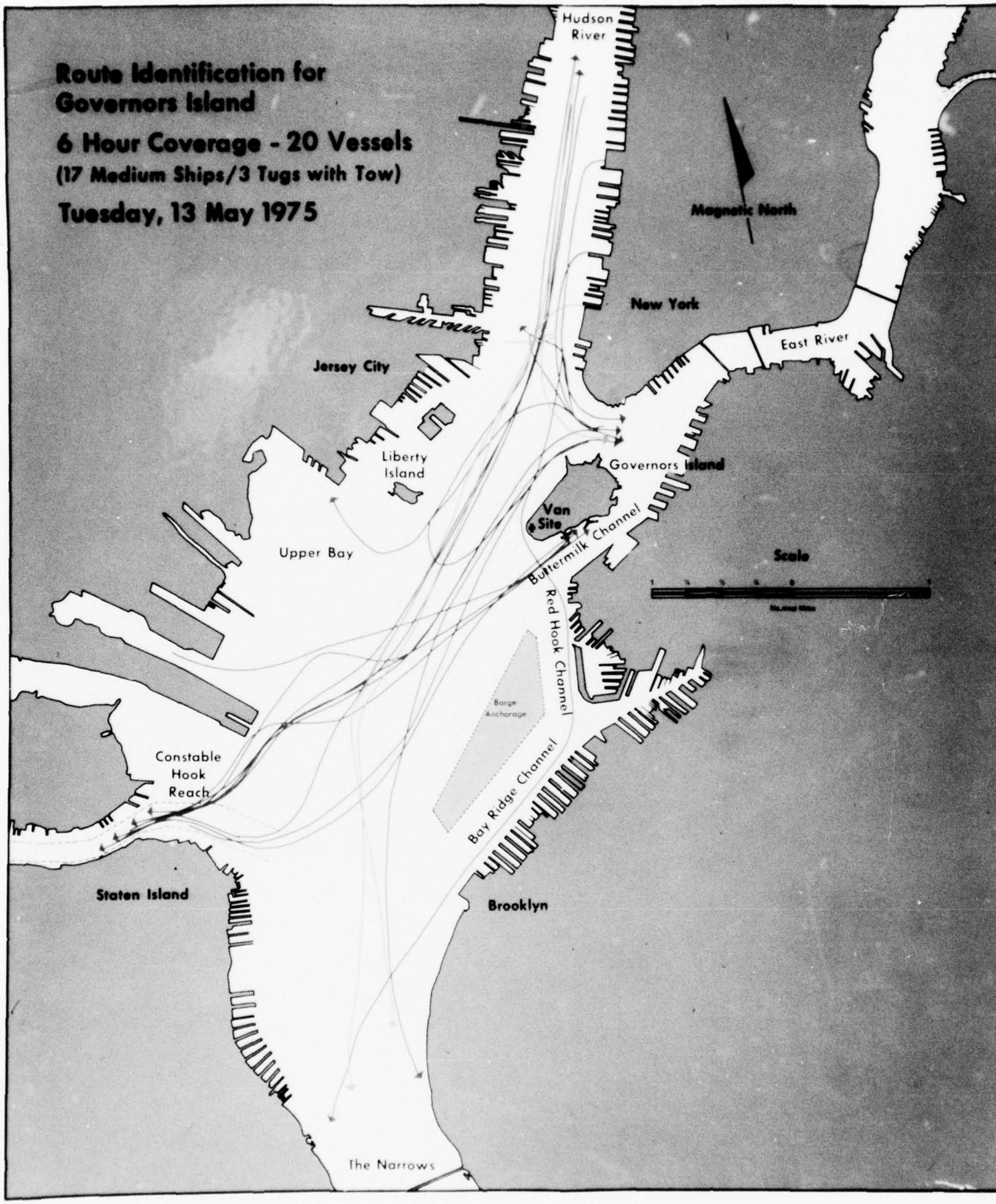
CHANNEL TRAFFIC

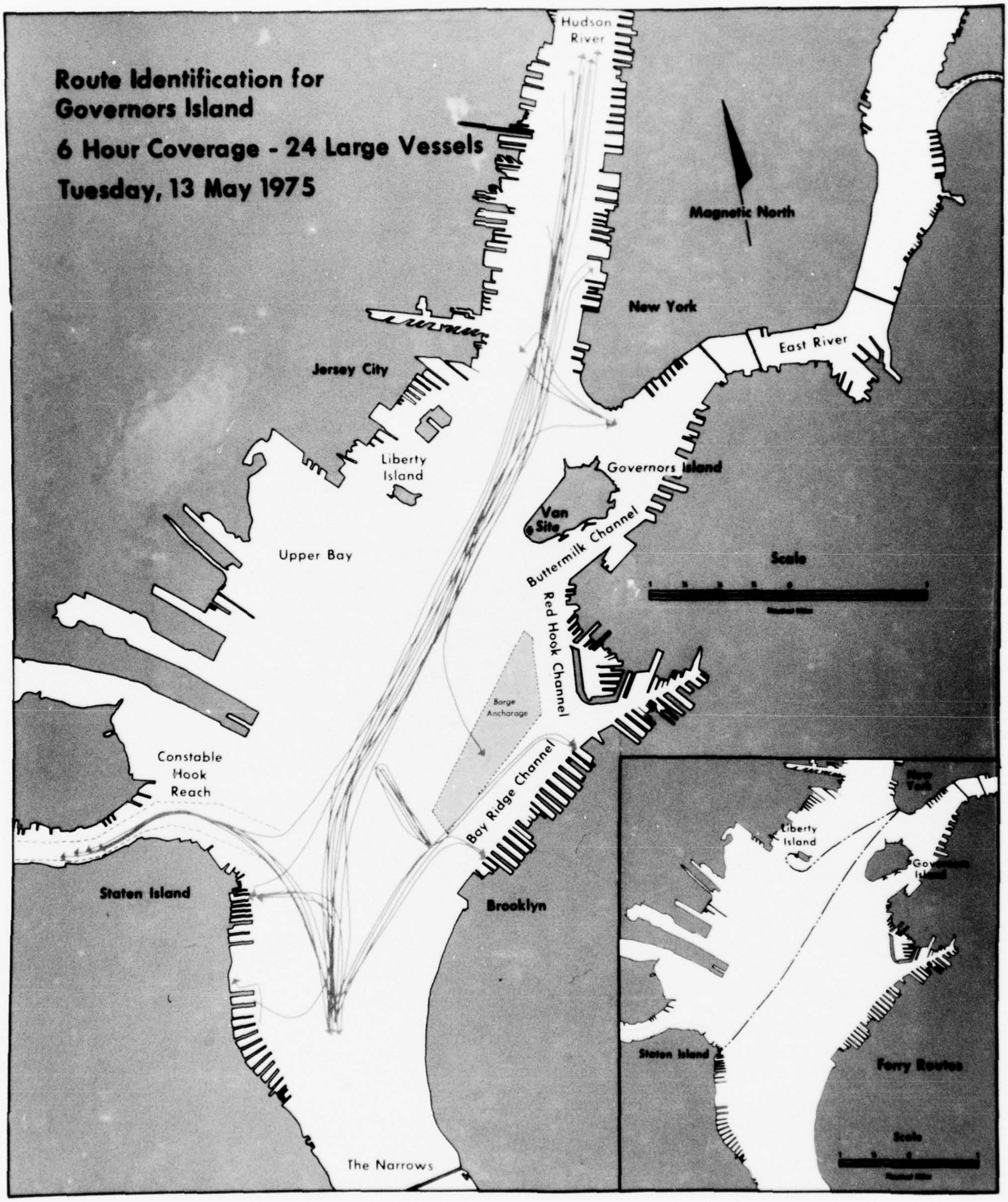
Check Point	Ships Entering Tug	Ships Entering Large	Ships Entering Small	Ships Leaving Tug	Ships Leaving Large	Ships Leaving Small
A	1	2			6	
C		1	6			3
E			11		1	4
G		3	3	1		5
I		1	3			5

Route Identification for Texas City Dike
3 Hours-Coverage-94 Extrachannel Vessels
Tuesday, 4 July 1974


Texas City Dike
Texas City Channel
B
Intracoastal Waterway
J
Bolivar Peninsula
D
Houston Ship Channel
H
Bolivar Roads Channel
F
Intracoastal Waterway
Pelican Island
Small Ships
Large Ships
Tug
Route Identification for Texas City Dike - Detail
3 Hours Coverage - 26 Vessels
Tuesday, 4 July 1974


Route Identification for
Governors Island
6 Hour Coverage - 44 Small Vessels
Tuesday, 13 May 1975
Hudson River
Magnetic North
New York
East River
Jersey City
Liberty Island
Governors Island
Van Site
Buttermilk Channel
Upper Bay
Scale
Red Hook Channel
Barge Anchorage
Constable Hook Reach
Bay Ridge Channel
Staten Island
Brooklyn
The Narrows


Route Identification for
Governors Island
6 Hour Coverage - 20 Vessels
(17 Medium Ships/3 Tugs with Tow)
Tuesday, 13 May 1975
Hudson
River
Magnetic North
New York
East River
Jersey City
Liberty
Island
Governors Island
Van
Site
Buttermilk Channel
Upper Bay
Scale
Red Hook Channel
Barge
Anchorage
Constable
Hook
Reach
Bay Ridge Channel
Staten Island
Brooklyn
The Narrows


Route Identification for Governors Island
6 Hour Coverage - 24 Large Vessels
Tuesday, 13 May 1975
Hudson River
Magnetic North
New York
East River
Jersey City
Liberty Island
Governors Island
Van Site
Buttermilk Channel
Scale
Upper Bay
Red Hook Channel
Barge Anchorage
Constable Hook Reach
Bay Ridge Channel
Staten Island
Brooklyn
The Narrows
New York
Liberty Island
Governors Island
Staten Island
Ferry Routes
Scale

At Eatons Neck Point site on Long Island Sound, another aspect of traffic patterns was found to be of interest — variation of traffic with time of day. At this site there emerged from the vessel density data evidence of a daily cycle, with numerous large and few small vessels present during the early morning hours, and numerous small and few large vessels present during daylight hours. Two route identification charts were thus prepared, one for 0000 to 0800 hours showing numerous large vessels, and one for 0800 to 1600 hours showing numerous small vessels. These charts are given in Figure 2.6.

On occasion, the complexity of traffic patterns at a site can necessitate special route identification treatment. Two examples of this are the Texas City Dike site (Port of Houston report) and the Governors Island site at New York harbor. (Both charts are presented in Figure 2.6).

At the Texas City Dike site, traffic channels are dredged out of otherwise extremely shallow water. The channels meet in center of the site, where an open area of interchange among the channels is also dredged clear. Outside of the central interchange area, almost all vessels are channel-dedicated, since leaving channels would mean running aground. Within the central area, highly complex traffic patterns emerge as vessels cross, traveling from channel to channel. The complexity of the picture is compounded by high vessel density, with counts peaking at 53 vessels present. At this site, two route identification charts were prepared for a three-hour peak traffic period. One is of the central area only. There, vessels which entered and left the area by way of one of the five converging channels are depicted. The second chart shows traffic in the rest of the site, but since most of this traffic is contained within channels, paths of these vessels would over lap. Thus, only routes of extra channel traffic are shown, while indications of the traffic levels within channels are given by traffic flow counts at channel check points.

The Governors Island site is similar to Texas City Dike, with complex traffic patterns and high level-density. There is a major difference, however, in that water depths vary at the site, and many vessels can travel outside channels. For this site, three route identification charts were prepared showing, for a period of peak traffic, routes of three vessel type distinctions.

These four variations of the basic route identification chart (Portsmouth, Eatons Neck Point, Texas City Dike, and Governors Island) represent cases where traffic patterns call for modification of route identification treatment. In deciding upon the treatment to be given to a particular site, the knowledge of the site gained through the vessel density data extraction process becomes vital. And since the data display is so reliant on visual aspects, the effect to be created in the final form of the route identification chart must always be kept in mind.

Once the route identification treatment has been layed out, preparation is nearly completed. Vessel type classification should be the same as for vessel density. In choosing the colors to be used in tracing routes, the main consideration is that they be identifiable in a darkened room, though there is also some advantage to keeping the same color code as will appear on the final chart. The last two preparation decisions — how many people are required and should the site be divided into sectors — are made on the same basis as for vessel density.

2.2.2 Data Extraction

- Projector Set Up

  1) Reel the selected radar film of high density (derived from vessel density results) on the projection.

  2) Place the projector at a distance from the projection surface, so that the vessels are clear, distinguishable, and so the projector is at right angles to the projection surface. The projector should not be moved while extracting data.

- Projection Surface Set Up

  1) Trace the background features. This background outline can aid in assuring that the projected image does not wander.

  2) Locate and mark radar location (center of scope). Use portion of film where the radar sweep is observable. Stop the film at frames where the sweep line is visible in 3 or 4 different sections of the scope, and trace the line each time. The intersection of these lines is center scope.

- Procedure

  Start the projector at the beginning of the time interval decided upon. Run the projector until a moving vessel appears. Select the colored pen for the type of vessel it is. Run the projector and trace the vessel wherever it travels, until its image is not observed any longer. Place an arrow at the end of its course pointing in the direction it traveled. Run the film in reverse until the vessel just traced is at the beginning of its course. Run the projector forward, repeating the process for the next moving vessel observed, and so forth until a desired maximum number of vessels are recorded or a maximum amount of time is observed. Record the number and type of vessels on each route as they are observed. Recording alongside the route is recommended.

- Recommendations

  1) Where section divisions are used it is recommended to trace all vessels starting in one section during the period and then repeat the process, section by section.

  2) When two people are needed it is recommended that one person run the projector, while the other person traces and records the vessels.

3) At the point when a vessel to be traced first appears, stop film and check that the background returns are in line with the previously traced outline.

4) If there is no predetermined time period, trace vessels until the waterways are full or until 24 hours of coverage is reached.

- Preparation For Producing the Final Route Identification

1) Place the radar film of the rings on the projector. (Projector must be in same position as at time of tracing.)

2) Run the projector until the rings of the scale needed are shown.

3) Place the center of the tracings of the vessels at the center of the rings film.

4) Trace the rings onto the diagram of the routes with a compass.

5) List the following on the diagram.

a) All locations to be designated on the final route identification.

b) Shadow areas observed.

c) At anchors observed.

d) Types of vessels present with their associated color code.

e) Name of site, total number of vessels present, day covered and number of hours covered.

An example of a Route Identification tracing is given in Figure 2.7.

2.2.3 Data Display

The final route identification chart is prepared from the route identification tracing from film in the following manner:

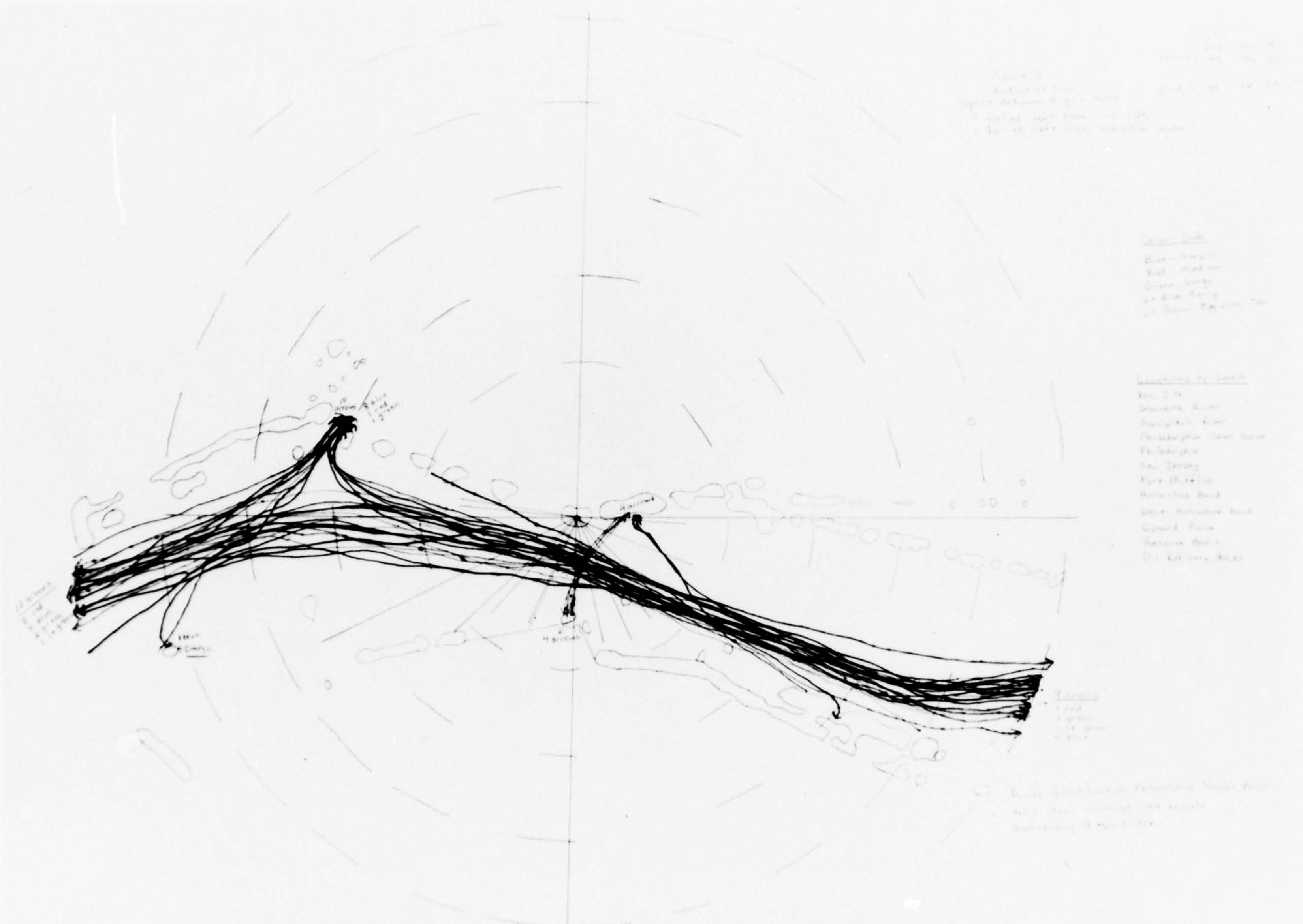
Obtain USGS Map or National Ocean Survey Chart, and any additional charts or maps helpful in marking channels, van sites, towns, or other relevant points.

Calculate size of base map (using proportional scale) needed to cover all ship routes to the same scale that the tracing taken from the film is set up to be. (Scale is usually set up for nautical miles or for larger scale charts, in feet or yards).

Figure 2.7

AN EXAMPLE OF A ROUTE IDENTIFICATION TRACING

is given on the following page



Color Code
Blue - Small
Red - Medium
Green - Large
Lt Blue - Ferry
Lt Green - Tug with Tow
Locations to Learn
Delaware River
Schuylkill River
Philadelphia Naval Base
Philadelphia
New Jersey
Fort Mifflin
Horseshoe Bend
Girard Point
Reserve Basin
Oil Refinery Area

Send out base map*(USGS or National Ocean Survey Chart) to be blown up to correct scale (should be able to cover a 20" x 24" image area. Photographer should return original map and a paper positive of the original at the size requested).

On a sheet of mylar, vellum, or other tracing paper, draw a 20" x 24" border with a heavy line (rapidograph No. 3 or 4). Move tracing paper around on map to contain all ship routes. Trace shore lines (No. 2½), ship channels, dumping grounds, testing sites, ferry routes, etc. (No. 1).

Label on the tracing, with prestype or headliner type, specific locations, such as towns, states, bodies of water, ship channels, etc., mentioned in the report. Also put down type for legend (covering ship types to be shown in the route identification), title of drawing, hours of coverage, number of ships to be shown, and date of film. Draw on scale and magnetic north arrow and label these accordingly.
(NOTE: Make sure that none of these labels will cover the paths of the ships to be shown).

Send* this sheet to photographers and have a mat film positive made at 100%.

Upon receiving film positive, overlay on tracing taken from film and mark ship routes by laying colored tapes (1/32") over routes made by ships. Use a different color for each ship type. Mark direction of ships with a corresponding colored arrow pointing in the direction the ship is moving. Use ¼" tape in corresponding colors for legend of ship type. (Example: red=large ships, green = medium ships, blue = small ships, etc.).

Overlay green acetate mat film to cover land areas. Cut around land areas and border with an exacto knife and peel off excess.

Cut positive mat film to 20" x 24" borders. Mount on light gray paper or gray mat board. Tape down edges with transparent tape.

Send out* originals to photographers and request 8½" x 11" copies with a 3/4" binding edge.

Examples of Route Identification Charts can be seen in Figure 2.6.

2.2.4 Error Sources

All of the errors associated with vessel density counts (shadows, bright center returns, side lobe effects and multiple returns, noise, and miscounting) and type classification (differing returns due to ship movements, differing returns due to radar intensity variations, borderline cases, radar range, and behaviorial classification) also affect the route identification data since it is based on identifying vessels on the PPI. Error in the position plot tracing of the vessel will result in errors in the location of lanes.

*Assuming in-house color photography service is unavailable

The accuracy of the position plot tracing will approach that of the radar since the plot is made from a radar PPI image. This excludes minor distortions due to the optics involved in the camera taking the pictures and the projector. Also, it should be realized that within a given harbor area most vessel routes are established and plotted on National Ocean Survey charts. In these cases, the precise locations of the routes are not important, but only the use of these channels, as measured by the number of vessels, is important. Only in cases where a non-standard route is discovered is the exact location of the route important and it is anticipated that heavy use of non-standard routes by vessels other than small boats will be rare.

The position of routes displayed on the final route identification chart, however, should not be considered to be precise, point by point, representations of the exact routes taken by vessels. Although each line does show a vessel path as accurately as possible, the distortion of the radar return does not allow for a direct transfer to a non-distorted chart presentation. It is highly likely that in correcting for this radar distortion, some error is introduced.

2.3 CLOSE ENCOUNTERS

2.3.1 Preparation and General Comments

Preparation for this type of data extraction includes determining two sets of criteria, one for "encounter" and another for "close encounter". In general, an encounter occurs when one vessel enters the vicinity of another in such a way that it passes, crosses, or overtakes the other. The use of "vicinity" in this definition is some what ambiguous, but it must be since the concept of vicinity may vary from site to site depending on traffic patterns, route constrictions, vessel speeds and density. Identifying encounters thus becomes judgmental. However, in practice, the identifying of encounters at a given site by use of radar films is quite a natural process and usually an encounter situation is self-evident.

A close encounter is one in which the distance between the center points of the two vessels, at their closest point of approach, is within a certain limit. Numerous considerations can enter into the determination of this limit. Physical factors (channel and waterway widths, tides and currents, critical traffic areas) measurement factors (percentage of error in measurement, relative size of vessels, radar resolution and intensity variations) all affect whether a given encounter should be considered close.

There are three alternative approaches to determining a close encounter. The first would be to relate all of the definable considerations in a dynamic close encounter model, and then apply the model to each encounter during a sampling period. As the development of such a complex model was prohibited by the scope of the project, this approach has not been used.

A second approach is to analyze the physical factors at a given site, and divide the site into areas of similar physical characteristics. Then, based on these physical constraints plus measurement considerations, assign

a fixed close encounter limit to each of the site divisions. Thus an encounter would be deemed close in a given area based on certain elements relevant to the encounter, while allowing for the use of a fixed distance standard to identify the encounter as close. A variation of this approach was used in the close encounter data extraction for the first harbor area of the series. The resultant data had a significant drawback, however, in that there is no common basis with which to compare data from numerous sites.

The obvious solution to the problem of comparing the data from site to site would be the definition of a universal close encounter distance. The variation in measurement factors among sites with radii ranging from 0.75 to 12.0 nautical miles is too great to allow a fixed distance to be applied to all situations. The third approach, which was used in the seven following harbor area reports, is based on the universal close encounter distance concept, with modifications for radar scale. With this approach, the distance which is the close encounter limit varies with radar scale, but is the same for all sites at a given scale. The limits used are:

Scale	Radius	Limit
6	12nm	400 yds.
5	6nm	300 yds.
4	3nm	200 yds.
3	1.5nm	150 yds.
2	.75nm	100 yds.

Once the criteria for "encounter" and "close encounter" are set, there remains only the practical decisions of how many people are required and should the site be segmented. These decisions are made based on the same considerations as for vessel density.

2.3.2 Data Extraction

- Close Encounter Distance Factor Conversion

  1) Reel the radar rings on the projector until the scale of the site is observed.
  2) Place the projector at a distance where the vessels are distinguishable, and so the projection is at right angles to the projection surface.
  3) Procedure to calculate the close encounter distance in inches.
     a) Convert the amount of nautical miles given between the rings to yards. Ex. For scale 3 - one ring distance= .25nm = 500 yds.

b) Measure the distance observed with a ruler. Ex.
1 ring space = 3.4 ins.

c) Calculate the amount of inches for a close encounter.
Ex. 150 yds = a close encounter

$$\frac{150 \text{ yds}}{500 \text{ yds}} = \frac{X \text{ ins.}}{3.4 \text{ ins.}} \quad X = 1.02 \text{ inches}$$

1.02 = the greatest distance allowed to define a close encounter.

- Projector Set Up

Place the radar film used for route identification on the projector. Leave the projector in the same place used for the factor conversion above. Projector must remain in this position throughout data extraction.

- Projection Surface Set Up

Trace the background features. This is recommended when sector divisions are used, or whenever stationary features are desired to be marked, and as a check of projection image positioning.

- Procedure

Run the projector until the first time to count is observed. Run the projector until vessels appear to be within the close encounter range. Stop the projector and measure at point of closest approach. When a close encounter exists, measure the distance between the center points of the two vessels. Record information required on the input form: time, distance in inches, size of vessels, and whether vessels are passing (approaching each other from opposite directions) overtaking (approaching while traveling in the same direction) or crossing. Count total encounters as observed while counting close encounters, or count separately. Continue this process until the desired number of close encounters is observed or a maximum amount of time coverage has been observed.

- Recommendations

1) Where section divisions are used it is recommended to count encounters and close encounters section by section.

2) When two people are needed it is recommended that one person run the projector, while the other person measures and records the close encounters.

3) Count close encounters until at least 50 are observed or until 24 hours of coverage are observed.

4) When two people are needed, have the person that runs the projector correct the total encounters as they occur, keeping a running total.

5) A shorter method to calculate the close encounter distance.

   a) Convert the amount of nautical miles given between the rings to yards.For scale 5, 1 nautical mile = 2,000 yds.

   b) Measure the distance between the rings with a ruler. If the distance is not a whole number in inches move the projector either closer or further away from the projection wall; whichever direction will change the distance between the rings to the nearest whole number. Ex 1 ring space = 2 inches.

   c) Calculate the amount of inches by the same method mentioned earlier. Ex. $\frac{300 \text{ yds.}}{2{,}000 \text{ yds.}} = \frac{X \text{ ins.}}{2 \text{ ins.}}$

   X = .30 inches

   This method allows one to measure close encounters quicker than the other method.

2.3.3 Data Display

The final form of close encounter data is a table giving date, time, distance in yards, size of vessels, and manner of approach for each close encounter recorded, with a statement of length of coverage period and total encounters of the period at the end. This data can be taken directly from the recording form, with the minor exception of distance conversion. Examples of the data recording form and a close encounter table are given in Figures 2.8 and 2.9.

2.3.4 Error Sources

Since all information other than size and distance given about a close encounter is considered descriptive, discussion of error sources for such information is not appropriate. Error sources will be considered for distance measurements, size statements, close encounter counts, and encounter counts.

Since distance measurements are taken at the closest point of approach, film of an encounter is stepped, frame by frame, until this point is reached. However, each frame is 4 or 5 seconds apart. Thus, the closest point of approach may be between frames, and the distance measurement taken up to 2.5 seconds before or after this point is reached. The amount of error thus introduced depends on the speed of the vessels and the angle of approach. As a worst case, consider vessels each at 30 knots, approaching from opposite directions. The maximum distance measurement error in this case is $\pm$4.2 yards.

A second error source in close encounter distance measurement is in locating center points of vessels. The impact of this factor depends on radar scale, radar intensity, and size of vessels encountering. As radar scale increases (area of coverage decreases) the radar return for a vessel becomes more distinct, making center location more accurate. As radar intensity increases, the radar return for a vessel blooms making center location less accurate. As the size of the vessels encountering increases, the error bounds for center location expand. A general statement of the magnitude of center location error bounds is $\pm$ one half the greatest measured diameter of a vessel radar return times a conversion factor.

A third distance measuring error source comes from the scale of measurement, and is equal to $\pm$ one half the length of the smallest scale division times the conversion factor for scale divisions to yards.

The last distance measuring error source is in the conversion factor itself. It is derived by measuring the radial distance between two rings with a scale, and converting this distance to yards using 1nm = 2,000 yds. (which is slightly inacurate since 1nm = more precisely 6076.1). The value of this error depends on the accuracy of the radar rings, the length of the smallest division of the measuring scale, the radar scale, and the size of the image projection. Decreases in either of the last two factors can lead to dramatic increases in error limits.

The errors involved in the size statements and counts of encounters and close encounters are essentially all those listed as sources for error in vessel density counts and type classifications, however, since encounters involve two ships, the probability of one type of error applying to both vessels is low, and thereby the effect of these error sources on close encounter data is diminished.

CLOSE ENCOUNTERS

Site = Governors Island   200yds = 4ins

	TIME	Distance (Ins.)	SIZE	MODE
1	061449	.2	L/S	P
2	061520	.4	L/S	P
3	061948	.2	L/L	P
4	061900	.4	S/S	O
5	062113	<.2	L/L	P
6	062456	.2	S/S	P
7	062635	<.2	L/S	P
8	062636	<.2	M/L	P
9	062825	.2	L/L	P
10	062934	.2	M/M	P
11	063213	<.2	L/M	Cross
12	063334	<.2	L/L	P
13	063259	.3	L/M	P
14	063501	<.2	L/L	P
15	063501	<.2	S/S	P
16	063542	<.2	L/L	P
17	063654	.3	M/S	P
18	063758	<.2	L/S	P
19	063929	<.2	M/S	P
20	063929	.3	L/S	O
21	064023	<.2	L/S	P
22	064141	.3	L/M	P
23	064159	<.2	M/L	P
24	064249	<.2	L/M	O
25	064546	<.2	M/S	P
26	064654	<.2	L/S	O
27	064703	.3	L/M	P

Figure 2.8

CLOSE ENCOUNTER RECORDING FORM

CLOSE ENCOUNTER FOR GOVERNORS ISLAND

Vessel #	Day	Time Hours	Time Minutes	Distance Yards	Size	Manner of Approach*
1	Tuesday 13 May 1975	06	14	100	1 large, 1 small	P
2		06	15	200	1 large, 1 small	P
3		06	19	200	2 small	O
4		06	19	100	2 large	P
5		06	21	100	2 large	P
6		06	24	<100	2 small	P
7		06	26	100	1 large, 1 small	P
8		06	26	<100	1 large, 1 medium	P
9		06	28	<100	2 large	P
10		06	29	100	2 medium	P
11		06	32	100	1 large, 1 medium	C
12		06	32	<100	1 large, 1 medium	P
13		06	33	150	2 large	P
14		06	35	<100	2 large	P
15		06	35	<100	2 small	P
16		06	35	<100	2 large	P
17		06	36	<100	1 medium, 1 small	P
18		06	37	<100	1 large, 1 small	P
19		06	39	<100	1 medium, 1 small	P
20		06	39	150	1 large, 1 small	O
21		06	40	<100	1 large, 1 small	P
22		06	41	150	1 large, 1 small	P
23		06	41	<100	2 large	P
24		06	42	<100	1 large, 1 medium	O
25		06	45	<100	1 medium, 1 small	P
26		06	46	<100	1 large, 1 small	O
27		06	47	150	1 large, 1 medium	P
28		06	49	<100	2 large	P
29		06	49	<100	2 large	P
30		06	51	<100	1 large, 1 small	P

*P = Passing
O = Overtaking
C = Crossing

Figure 2.9

CLOSE ENCOUNTER TABLE

2.4 VESSEL SPEED

2.4.1 Preparation and General Comments

Vessel speed calculations are derived from two measurements for each vessel - a time measurement and a distance measurement. Since time measurements are taken directly from the clock displayed on the radar film, they require no special preparation. Distance measurements cannot be taken directly from the film, even though the radar scale is known. This is due to the blanking of the initial portion (approximately 1/3 of the radius to the first scale ring) of the radar return. This blanking causes each point of the radar return to be displayed on the radar scope a fixed distance closer to the center than the location at which it would be displayed if there were no blanking. Even though this fixed distance is known for each scale, the drawing of all points toward the center causes a distortion of the radar picture whereby linear measurements can only be made along radials. The preparation for extraction of vessel speed data therefore includes deciding upon a method for taking distances.

One distance method is the landmark method. It relies on fixed radar returns which can be identified on a chart of the site. If a given site has well traveled routes, which are marked by distinctive, identifiable radar returns, the distance between these "landmarks" can be measured directly from the chart. The advantage of this method is that taking vessel speeds becomes a simple process of clocking vessels as they pass the landmarks. The disadvantages are:

- Only vessels following the landmarked routes can be clocked. As the percentage of vessels transiting the prescribed routes falls, the vessels sampled become less representative of the site as a whole.

- There are error considerations which make the method too inaccurate for prescribed routes of short distances.

- Some sites have traffic patterns that are too open to define general routes.

- Some sites may have definable traffic routes, but no identifiable fixed returns marking them.

The second distance measuring method has far more general applications, but is also more complex. It is based on finding the distance between two points by considering this distance to be the third side of a triangle of which measurements are known for two sides and the angle they form. The distance between a point on the radar return and the center of the return can be measured and converted to the distance between the object (a vessel) and the radar location. This is possible since radial distances are linear, and the radar scale and distance of radar blanking are known. The angle formed by two such radial lines (from two points representing two vessel locations) can be measured directly from the radar film. With these figures and a trigonometric identity, the Law of Cosines, the distance between the points can be determined. Thus the distance between two vessel locations can be determined. This method can be applied directly to the measurement of distance traveled by a vessel in a given time, but many individual measurements are required for complete speed samples.

These two basic methods can be modified so as to require fewer measurements per speed calculation. One modification is to identify vessel routes and then use the Law of Cosines procedure to measure points along the route when landmarks cannot be identified. Speeds can then be taken in a fashion similar to the landmark method. A second modification is to prepare a transparency with distance rings and radial lines of predetermined size. Speeds can then be taken for vessels not following prescribed routes by timing them as they pass intersections of lines and circles.

Since each of the various methods of extracting vessel speed data have applications that are appropriate to different combinations of site factors, choice of method depends on the site. For most sites, one of the methods or modifications described here will apply. However, situations may occur at future sites which will call for the development of further modifications of one or both of the basic methods. Preparation for data extraction therefore, calls for analysis of the traffic patterns and fixed radar returns of the site, relative to the constraints of each speed method.

2.4.2 Data Extraction

2.4.2.1 Method I - Landmarks

- Projector Setup

  1. Place the radar film used for route identification on the projector.

2. Place the proejctor at a distance where the vessels are clearly distinguisable, and the projector is at right angles to the projection surface. Projector must remain stationary during data extraction.

- Route Setup

1. Decide on the stationary points to use that appear on the nautical chart and film. Use buoys, land areas, stationary vessels in the water, etc.

2. Mark exactly where they are on the nautical chart. Label each point, alphabetically for instance.

3. Measure the distance between each set of points with a ruler, and the scale of the nautical chart.

4. Convert the inches to tenths of a nautical mile (distance is now known).

- Projection Surface Setup

1. Mark the points acquired in Route setup, onto the background.

2. Draw the outline of the areas shown on the film, to mark stationary features.

- Procedure

1. Run the projector until a vessel passes one of the two points marking a distance.

2. Stop the projector and record the time. Run the projector until the same vessel passes the other point marking the distance and record the time. As many other vessel should be counted as they pass others on the same points.

3. Continue until the number of vessels to be recorded or the time period to be covered is reached.

4. Calculate the time traveled for each distance
Distance/Time = Speed

2.4.2.2 Method II - Law of Cosines

- Projector Setup and Projection Surface Setup

1. Put the rings film on the projector.

2. Draw the rings and mark the center of the scale for the site.

3. Take the rings film off and place the radar film that was used for route identification on the projector.

4. Mark the center of the radar film on the paper with the ring scales on it.

5. Projector must remain stationary during data extraction.

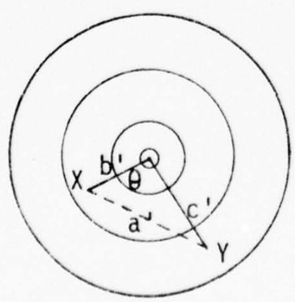
- Process to Mark the Center of the Radar Film

Draw straight lines connecting the center of the center reflection and the reflection that shows up at the end of the beam. (Before the radar picture of the site, there is some film with just the beam shown rotating - use this part of the film). Draw as many lines as necessary to get a good approximation where the center is (where the lines intersect). At the same time, move the scale rings background to match the film, center to center,

- Procedure

Start the radar film at the first time interval. When a vessel appears stop the film. Mark this point X and record the time. Then run the projector the longest distance that covers the vessel's route, or as long as vessel travels in a straight path. Stop projector and mark this point Y and record the time. Measure the distances between X and Y (a') and from X to center (b') and Y to center (c'). Use these measurements (do not apply scale factor) to determine angle θ. Then convert measured distances b' to c' to real distances b and c in yards. Find real distance a, as shown in Figure 2.10.

FIGURE 2.10 DISTANCE CALCULATION



Use a', b', c', and Law of Cosines to find θ.
Convert b', c' to real distances b and c.
Use b, c, θ and Law of Cosines to find real distance a.

When vessels travel on the radial-record the time between the two points and the distance. Convert directly to yards. Repeat this procedure until the desired number of vessels are counted or the desired amount of time is covered. The angle θ and distance a can all be computed using the following formula:

$$a = \sqrt{b^2 + c^2 - 2bc \cos \theta} = \text{Distance}$$

Then calculate the speed from the following formula:

Distance/Time = Speed

2.4.2.3 Modifications to Methods I and II

- Use a combination of Method I and II when a route(s) is to be used for the speed calculations, and no landmarks exist to denote it.

  Procedure:

  1. Mark the points of the route on the projection surface.
  2. Calculate the distance using the Law of Cosines equation method.
  3. Use the derived points to take speeds as described in Landmarks procedure.

- Use a scale diagram (made on transparency paper) to calculate distances when specific routes cannot be identified.

  Procedure:

  1. With the range rings on the projector draw the rings onto mylar film or tracing paper. Mark the center of the rings. (The projector must remain stationary during data extraction)
  2. Draw 5^0 (recommended) angles radially from the center.
  3. Set the radar film (that was used for the route identification) on the projector.
  4. Mark the center of the radar film.
  5. Place the center of the scale diagram at the center of the radar film.
  6. Record a vessel's time and distance from the center as it passes an intersection of radial line and ring. Record the time it passes its last intersection* of radial line and ring, and the distance the ring is from the center. Then record the angle the vessel traveled.
  7. Count as many vessels as desired and for as long as desired.
  8. Calculate the distance with the following formula:

$$a = \sqrt{b^2 + c^2 - 2bc \cos \theta} = \text{Distance}$$

* (As long as vessel stays on straight path)

This procedure requires fewer calculations since distances don't have to be measured separately - rings and angle divisions are merely counted. For an application example, see Figure 2.11.

2.4.2.4 Recommendations

1. When two people are working on speed data extraction, it is recommended that one person run the projector while the other person measures and records the data collected.

2. Take speed data until at least 50 are recorded.

3. Draw the paths used for the Landmarks method in a diagram format, for future use.

Examples of the data recording sheets used for Landmark and Law of Cosines methods of vessel speed data extraction are given in Figures 2.12 and 2.13. A diagram of speed timing calculation points is given in Figure 2.14.

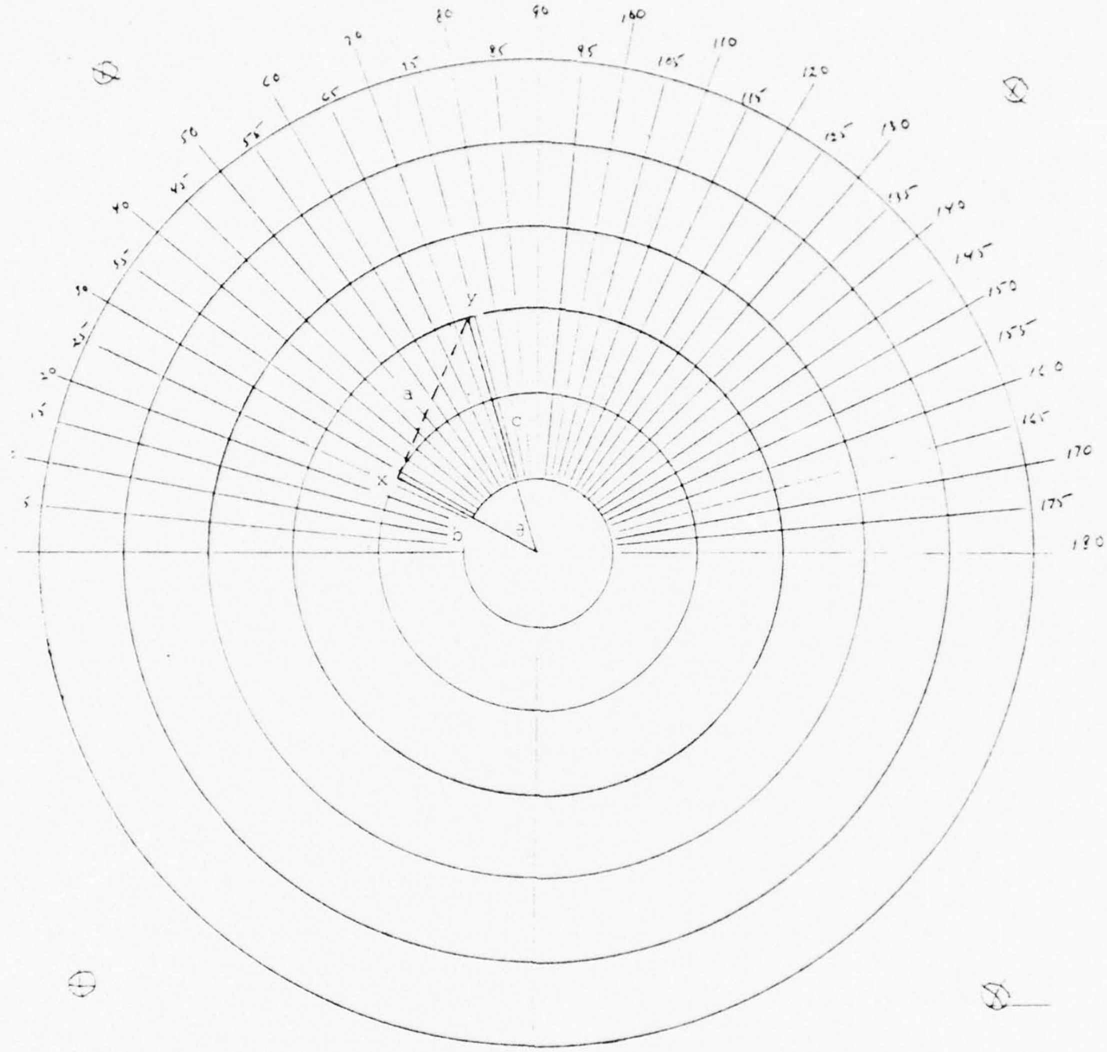
2.4.3 Data Display

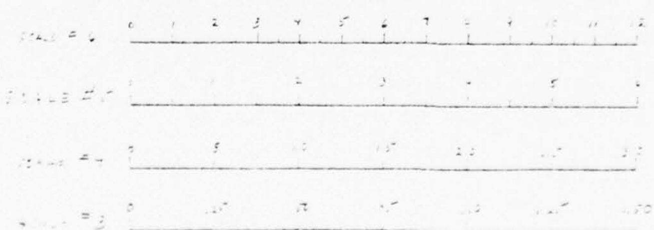
Vessel speed data is displayed in two final products. The first is a table of speed data giving vessel size, location, and time of speed sample for each speed calculated. The second is a histogram showing the distribution of the speed sample. The histogram has vessel speed in knots for abscissa, and number of ships for ordinate. Site, sample size, and date are given on each histogram. Examples of these final speed data displays are given in Figures 2.15 and 2.16.

2.4.4 Error Sources

Since there is a variety of methods for vessel speed extraction, one set of error sources does not apply to all speed data. The following will address various types of possible error elements, and indicate the type of speed extraction to which they apply. All speed calculations are composed of two types of measurements,time and distance. Error sources for these two components will be considered separately.

- Time - time measurements are all read directly from the clock on the radar film, which displays time once per 360^{o} radar sweep, which is once per frame. The time given by frame is separated by at most 5 seconds. Thus the error limit for each individual time reading is $\pm$ 5.0 seconds. The percent of error introduced to the time measurement depends on the length of the time measurement and is ($\pm$ 5.0 sec/difference of two time readings). This error factor applies to all types of speed extraction.





With each angle a multiple of 5° and 2nm between each ring

$c = 6nm$

$b = 4nm$

$\theta = 45^{\circ}$

FIGURE 2.11

APPLICATION EXAMPLE FOR TAKING DISTANCE MEASUREMENTS USING RING AND ANGLE TRANSPARENCY

Site = Governors Is — Day = 133 — Page = 1 — (1)

#	Size	At	Time	At	Time	At	Time	At	Time	At	Time	Remarks
1	L	A	061358	E	062943							6.4
2	L	A	062015	E	063420							7.7
3	L	A	062546	I	063622	B	065032	G	070545	F'	071910	[illegible]
4	L	A	063231	E	065307							[illegible]
5	M	A	064302	I	065023							13.1
6	L	A	061721	F	075451							7.4
7	L	E	072513	C	075442							8.8
8	M	E'	074658	C	090707							10.3
9	M	E	080603	A	082100							7.3
10	L	A	075955	B	092329	G	093739	F'	085004			3.7
11	L	F'	071725	D	073428							5.9
12	T/T	F'	072149	I	080911							[illegible]
13	M	F'	072423	D	074248							[illegible]
14	L	F	073442	F'	074157							[illegible]

FIGURE 2.12
SPEED DATA RECORDING SHEET
FOR LANKMARK METHOD

Speed

A, B = 2 sides
C = [illegible] traveled

[illegible]
Scale 6

$a = \sqrt{b^2+c^2-2bc\cos A}$

Vessel No. 28	Vessel Size	Range In Miles B	C	∠	Direction	Day	Time				Day	Time				Dist	Speed
1	[illegible]	→ Dist = 4mi			SW	126	09	45	27	–	126	10	04	56	.32	4	12.5
2	L	4	8	[illegible]	W	↑	10	14	18	–	↑	10	52	28	.64	4.08	6.37
3	S	→ Dist = 2 mi			SW		10	23	42	–		10	48	2[illegible]	.41	2	4.8[illegible]
4	L	→ Dist = 2mi			SW		11	03	41	–		11	[illegible]	[illegible]	.17	2	11.76
[illegible]	L	[illegible]		20°	E		11	04	36	–		11	[illegible]	[illegible]	.26	[illegible]	[illegible]
[illegible]	L	6	2	[illegible]	NE		13	04	33	–		13	2[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	L	→ Dist. = 4mi			SW		14	43	43	–		15	[illegible]	52	.32	–	[illegible]
[illegible]	T	6	10	27°	W		15	04	10	–		15	35	5[illegible]	.33	[illegible]	[illegible]
9	L	6	10	23°	W		15	3[illegible]	[illegible]4	–		15	51	5[illegible]	.42	5.05	12.03
10	T	6	12	23°	W		16	14	41	–		16	50	18	.54	6.39	11.67
[illegible]	L	4	10	02°	SW		16	4[illegible]	[illegible]	–		17	04	46	.44	6.00	13.6[illegible]
[illegible]	L	2	10	02°	SW		18	02	48	–		18	[illegible]	45	.62	[illegible].00	12.91
[illegible]	L	6	10	23°	W		18	50	39	–		19	12	2[illegible]	.36	5.05	14.04
[illegible]	L	10	4	29°	E		[illegible]	[illegible]	[illegible]	–		19	40	16	.84	6.78	8.08
[illegible]	T	10	6	24°	E		19	08	13	–		20	01	45	.89	5.14	5.77
[illegible]	L	Dist. = 6mi			NE	↓	19	45	21	–	↓	20	16	16	.52	6	11.54
[illegible]	L	6	10	19°	W	126	19	57	23	–	126	20	18	14	.35	4.75	13.56
[illegible]	[illegible]	10	6	31°	E	127	00	35	42	–	127	00	59	11	.39	5.76	14.76
11	L	6	10	19°	W	↑	01	42	53	–	↑	02	01	12	.31	4.75	15.31
[illegible]	L	6	10	22°	W		02	13	33	–		02	36	30	.38	4.97	13.09
[illegible]	L	6	8	6°	W	↓	07	05	15	–	↓	07	15	56	.18	2.13	11.82
[illegible]	L	6	8	18°	W	127	07	40	43	–	127	07	53	04	.21	2.95	14.04
2-27																	
[illegible]	L	10	6	19°	E	126	07	06	45	–	126	07	49	56	.72	4.25	6.59
[illegible]	L	10	6	19°	E		07	42	35	–		08	05	55	.39	4.75	12.18
[illegible]	L	6	8	01°	SW		09	00	19	–		08	[illegible]	06	.15	2.00	13.[illegible]
2-9	L	8	6	13°	SE	125	21	48	52	–	125	22	03	20	.24	2.54	10.5[illegible]
[illegible]	L	6	12	13°	W	125	21	48	43	–	125	22	25	41	.61	6.30	10.33

FIGURE 2.13

SPEED DATA RECORDING SHEET
FOR LAW OF COSINES METHOD

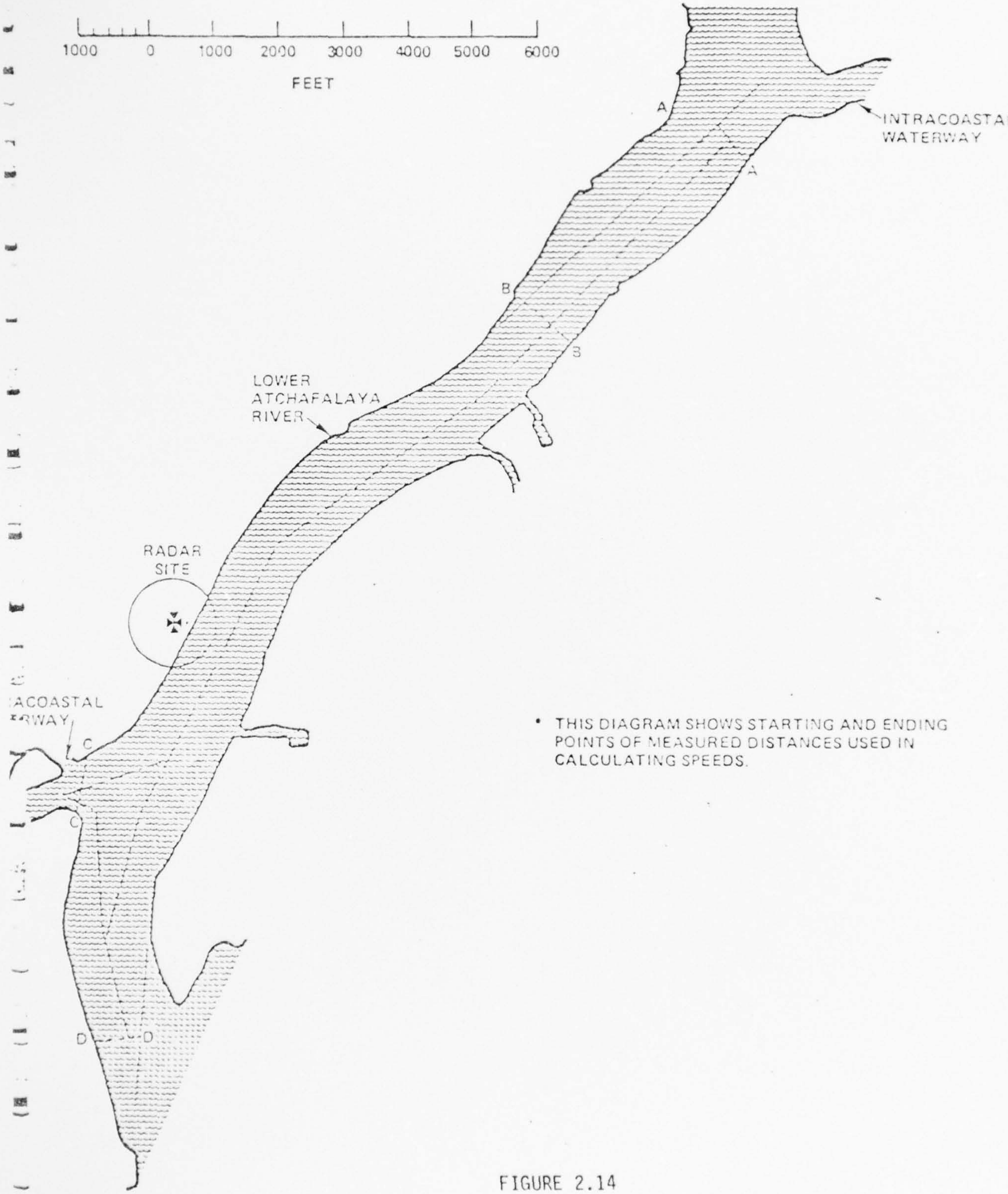


FIGURE 2.14

SPEED CALCULATION TIMING POINTS FOR ATCHAFALAYA*

SPEED DATA
FOR
GOVERNORS ISLAND

Vessel #	Vessel Size	Average Speed in Knots	Location*	Day	Time Hr.	Time Min.
1	large	7	A	Tuesday 13 May 1975	06	13
2	large	7	B		06	17
3	large	8	A		06	20
4	large	4	C		06	25
5	large	5	A		06	32
6	medium	13	C		06	43
7	large	6	F		07	17
8	tug with tow	7	F		07	21
9	medium	5	F		07	24
10	large	9	D		07	25
11	large	7	G		07	34
12	medium	10	D		07	46
13	large	4	C		07	59
14	medium	7	A		08	06
15	medium	10	H		08	11
16	medium	11	D		08	37
17	medium	7	H		08	51
18	medium	9	I		09	04
19	medium	9	F		09	07
20	medium	16	F		09	22
21	tug with tow	9	D		09	34
22	medium	12	F		09	34
23	medium	11	D		09	39
24	medium	10	J		09	40
25	medium	10	D		09	41
26	small	12	J		10	00
27	large	4	B		10	01
28	large	4	F		10	01

FIGURE 2.15
SPEED TABLE

SPEED DATA
FOR
GOVERNORS ISLAND (Cont'd)

Vessel #	Vessel Size	Average Speed in Knots	Location*	Day	Time Hr.	Time Min.
57	medium	13	D	Tuesday 13 May 1975	14	51
58	medium	11	K		14	53
59	medium	7	G		14	55
60	large	4	G		14	59
61	large	10	C		15	01
62	medium	11	G		15	06
63	small	15	G		15	14
64	small	12	G		15	15

* A - Between the Narrows and Constable Hook Reach
B - Between the Narrows and Hudson River
C - Between the Narrows and Upper Bay
D - Between Constable Hook Reach and Buttermilk Channel
E - Between the Narrows and Buttermilk Channel
F - Between Upper Bay and Hudson River
G - Hudson River
H - Between Constable Hook Reach and Upper Bay
I - Between Buttermilk Channel and Upper Bay
J - Upper Bay
K - Between Constable Hook Reach and Hudson River

FIGURE 2.15 (Cont.)
SPEED TABLE

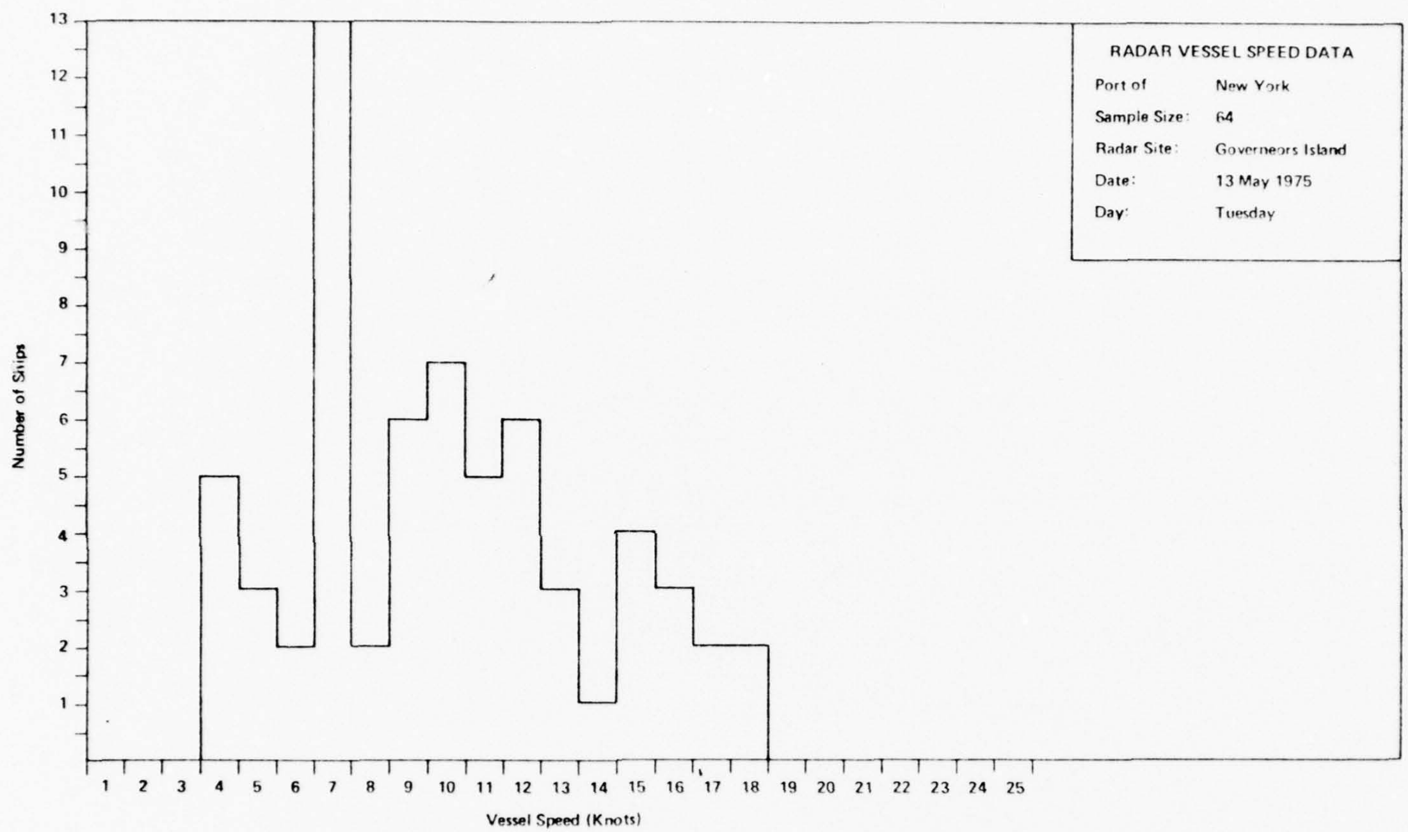


FIGURE 2.16
SPEED HISTOGRAM

For methods which measure time between fixed points (Landmarks and both recommended alternatives) and second time error consideration applies. Although the time is still taken directly from the radar film, the decision as to when a ship reaches a point is based on visual information (seeing the vessel reach the point) which is not necessarily precise. As a worst case estimate of the error, half of the largest diameter of a return from a vessel can be used. With a large vessel (1000 ft) traveling at 30 knots, this would result in a time error of 10 seconds. In practice, this can be higher since radar returns of vessels are considerably larger than the vessels themseleves, and it is the largest diameter of the return which must be used in this factor.

- Distance - distance measurements for speed extraction can be classified in two ways, fixed and varying. Fixed distance measurements apply to the Landmark and two recommended alternative methods. Varying distance measurements applies to the general Law of Cosines approach. The following factors affect each distance measurement made by this general approach.

1) Center Location of Vessel - the same considerations of error in locating vessel center apply here as for close encounter (section 2.3.4), however, since two centers must be located for one measurement, the general rule becomes($\pm$ one half the greatest measured diameter of a vessel radar return times a conversion factor) times two.

2) Center Location of Radar Image (Center Scope) - plotting the exact location of the center of the PPI for purposes of measuring radial distances to targets was subject to error. The center was located by drawing two radials from the outer range ring along two bearings as indicated on the outer ring of the PPI. The intersection of these radials was plotted as the center. This was verified where possible by drawing radials corresponding to the observed radar cursor at two different bearings. The error associated with this technique is $R \sin \theta$ where R is the length of the radial and θ is the angular error in the radial. Assuming a maximum error of .5 degree in θ and using 12nm for R, a worst case error in center location of 210 yards is obtained. In practice, this can be expected to be much lower since the radar cursor lines were generally available to determine center, which results in a very small R.

3) Measuring Distance - in measuring the distance between two points (x and y) on the PPI either directly from point x to point y, from the center of the radar PPI to points x and y, there is always the inherent error associated with the smallest division on the ruler used, which converts by a scale factor to an error limit of $\pm$ .5 (division length) times the conversion factor. This factor is more significant in the Law of Cosines determination of distance as three measurements are made for one distance.

4) Picture Distortion - projection of an image on a large surface can result in distortion. Care was exercised to eliminate this distortion by always projecting at right angles to the surface, but it is doubtful that any projection is absolutely distortion free.

5) Conversion Factor Error - this error is exactly the same as for close encounter, section 2.3.4.

Error source considerations for the various fixed distance measurements include:

1) Landmark Identification - one method relies on identifying landmarks on the radar film from charts (usually National Ocean Survey). This matching of points has three basic sources of error.

   - Matching of Points. Most lankmarks (bridges, land masses, etc.) have large radar returns, which makes precise location of the same point in both places difficult. Buoys provide smaller targets, but an error of 50 yards must be added for buoys, allowing for short-term drift.
   - Distance Measurement - even when taking distances directly from charts, the measurement is only as accurate as the chart and the measurement scale.
   - Misidentifying of Landmarks - Although it seems highly unlikely that a fixed radar return would be identified incorrectly, the possibility must be considered.

2) Measured Fixed Distance - When the endpoints of the given fixed distance are chosen such that the Law of Cosines rule is required to determine the distance between them, all of the error sources discussed for varying distance measurements apply to this distance.

3) Transparency Speed Form - the error sources involved in this type of distance measuring include accuracy of the circles and angles drawn on the transparency.

There is one further source of error which applies to every method of distance measurements. All distances are taken based on vessels following paths of straight line segments. While vessels may appear to be moving in a straight line, it is highly unlikely that any are ever moving in a perfect line, due to water movements. Thus all speed figures are slightly distorted.

2.5 CHANNEL UTILIZATION AND MESSAGE ACTIVITY

2.5.1 Definition of Terms

Channel utilization is the percentage of time that Channel 13 of the VHF/FM Maritime Mobile Band is in use, as recorded at a given site. That is, at each radar site this channel is audited and recorded. The time the channel is in use, per sample time, is its utilization.

Message activity is a count of the number of messages on the same channel, per sample period, with each break in squelch counted as one message.

2.5.2 Derivation of Data

The data is recorded, and utilization and activity figures derived, by an automated system developed by the U.S. Coast Guard R&D Center of Groton, Conn. A description of the system, as given in the Coast Guard publication "Statistics on Bridge-to-Bridge Frequency Usage at Selected Sites in the Eighth Coast Guard District" (Report No. CG-D-93-75) is as follows:

> "An interface circuit was developed to accept an audio input from a receiver or an analog magnetic tape recorder and timing data from a digital clock. The output of the interface circuit caused a paper tape punch to record the time of transmission and the message length on punched paper tape.
>
> "The interface circuit was composed of two parts: a message length register and an audio/logic converter. The audio/logic converter, converts the presence or absence of radio transmissions to one of two possible voltage levels (or logic states). Parenthetically

the background noise level on both the receivers and the tape recorders that were used on this task was virutally zero when no transmissions were being made. This simplified the transmission/no transmission recognition requirements.

"The other portion of the interface circuit was the message length register. The message length register measrues the length of the messages by counting the number of 10 Hz pulses received from the digital clock between the beginning and the end of the message. Also, at the end of each message this cirucit develops a pulse which commands the paper tape punch to commence a data punch cycle.

"Upon command from the message length register, the paper tape punch records the current time (received from the digital clock) and the message length on punched paper tape. The paper tape is then processed in a mini-computer. The computer program generates histograms for the time of transmission and for the message length from the data."

The data derived from this process are published in the form shown in Figure 2.17.

2.5.2 Data Display

Data is taken directly from the published lists and plotted on preprinted draft histograms, with times of day as abscissa and percent utilization for ordinate of channel utilization and number of messages as ordinate for message activity. Site and date information, is added, and the plots can then be easily traced in ink onto the final histograms. Examples of draft and final histograms are given in Figures 2.18, 2.19, 2.20, and 2.21.

13

VHF-FM Channel 13 Transmission Statistics, ~~14~~ May 1975
Message Transmission Time Histogram

PERIOD ENDING:	NUMBER OF XMSNS.	MINUTES:	PERCENT:
615	112	5.87	39.13
630	132	6.28	41.87
645	103	3.93	26.17
700	103	6.25	41.69
715	145	6.83	45.51
730	158	5.92	39.46
745	188	6.09	40.62
800	126	6.41	42.70
815	139	5.88	39.20
830	130	8.12	54.11
845	103	4.22	28.10
900	92	4.41	29.41
915	64	2.77	18.47
930	74	5.41	36.05
945	101	6.14	40.90
1000	102	6.69	44.62
1015	121	7.42	49.43
1030	137	7.61	50.75
1045	126	6.17	41.16
1100	156	9.03	60.20
1115	113	6.83	45.51
1130	93	5.11	34.09
1145	127	5.31	35.40
1200	127	6.25	41.67
1215	147	5.88	39.21
1230	136	5.72	38.15
1245	120	5.87	39.12
1300	77	3.58	23.87
1315	72	3.61	24.03
1330	41	1.92	12.80
1345	74	4.05	27.00
1400	91	4.54	30.23
1415	45	2.27	15.13
1430	94	3.67	24.46
1445	101	6.85	45.66
1500	110	7.13	47.56
1515	100	4.93	32.89
1530	102	5.65	37.66
1545	131	6.24	41.60
1600	123	5.57	37.16
1615	87	3.50	23.33
1630	91	3.83	25.55
1645	83	4.79	31.96
1700	91	5.54	36.92
1715	139	5.53	36.88
1730	152	4.58	30.56
1745	163	7.09	47.27

Figure 2.17

COMMUNICATIONS DATA - AUTOMATED PROCESS

VHF-FM Channel 13 Transmission Statistics (cont'd)

PERIOD ENDING:	NUMBER OF XMSNS:	MINUTES:	PERCENT:
1800	176	5.35	35.69
1815	233	5.69	37.91
1830	265	6.35	42.35
1845	247	7.62	50.77
1900	172	6.31	42.05
1915	139	7.23	48.22
1930	244	8.27	55.15
1945	231	9.20	61.33
2000	159	4.91	32.70
2015	108	5.89	39.26
2030	132	3.45	23.01
2045	128	6.73	44.83
2100	57	4.45	29.63
2115	9	0.49	3.28

TOTAL NUMBER OF TRANSMISSIONS: 7542
AVERAGE NR OF XMSNS: 123.64
STD DEVIATION: 49.66
TOTAL TRANSMISSION TIME: 5.6533 HOURS
AVERAGE LENGTH OF TRANSMISSION: 2.70 SEC.
PERCENT CHANNEL UTILIZATION; 37.07

Figure 2.17 (Con't)

COMMUNICATIONS DATA - AUTOMATED PROCESS

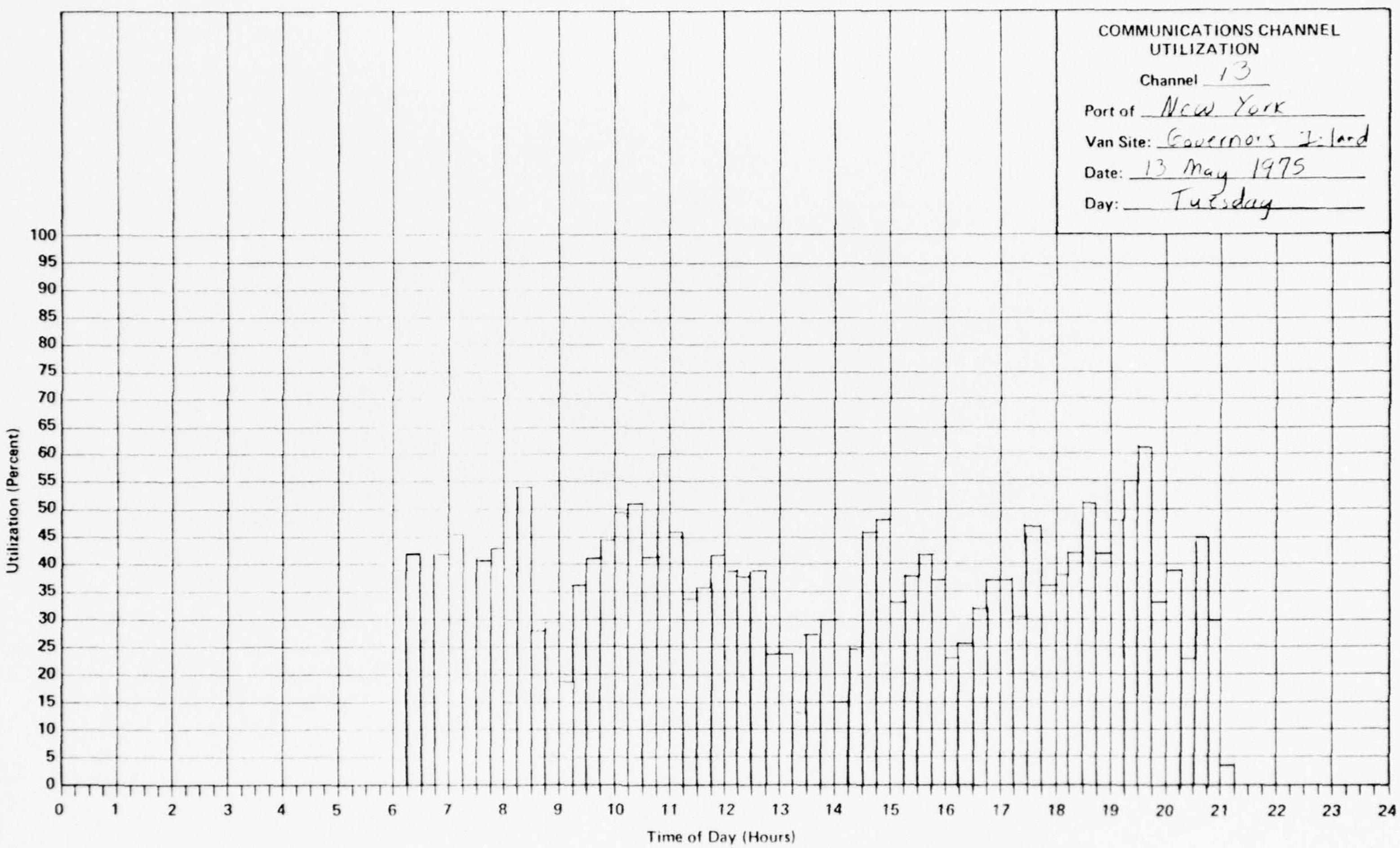


Figure 2.18

CHANNEL UTILIZATION HISTOGRAM, DRAFT FORM

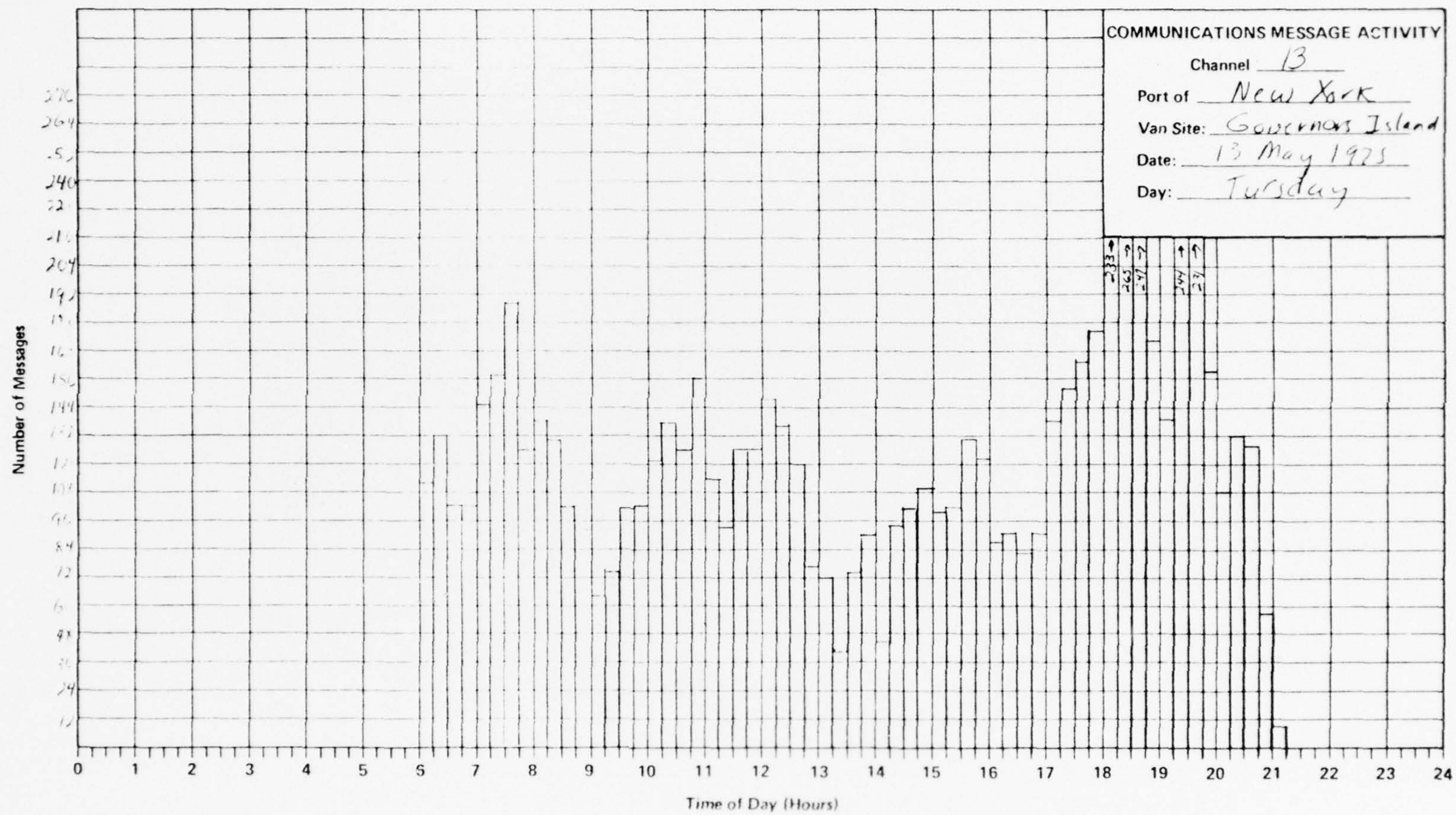


Figure 2.19

MESSAGE ACTIVITY HISTOGRAM, DRAFT FORM

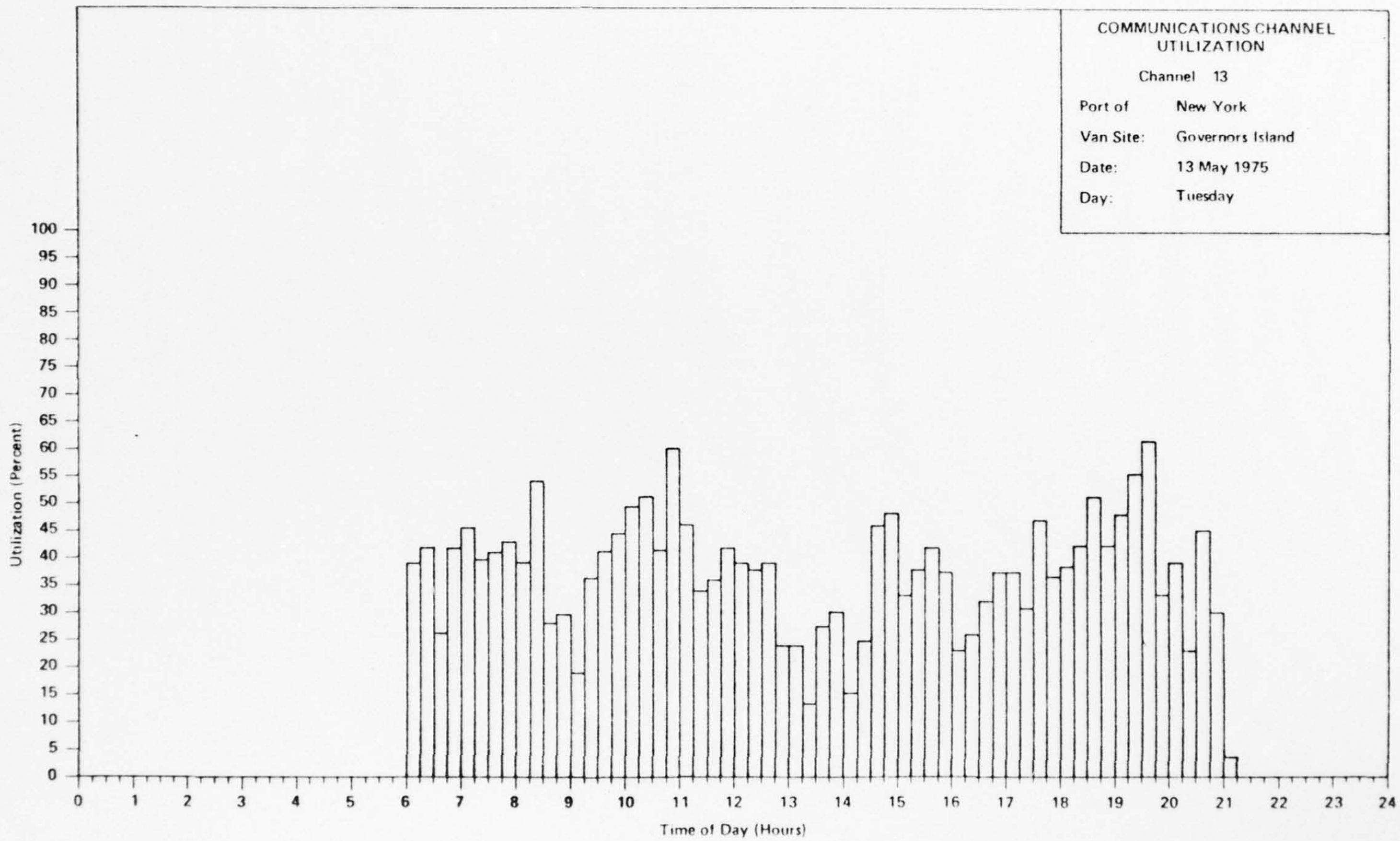


Figure 2.20

CHANNEL UTILIZATION HISTOGRAM, FINAL FORM

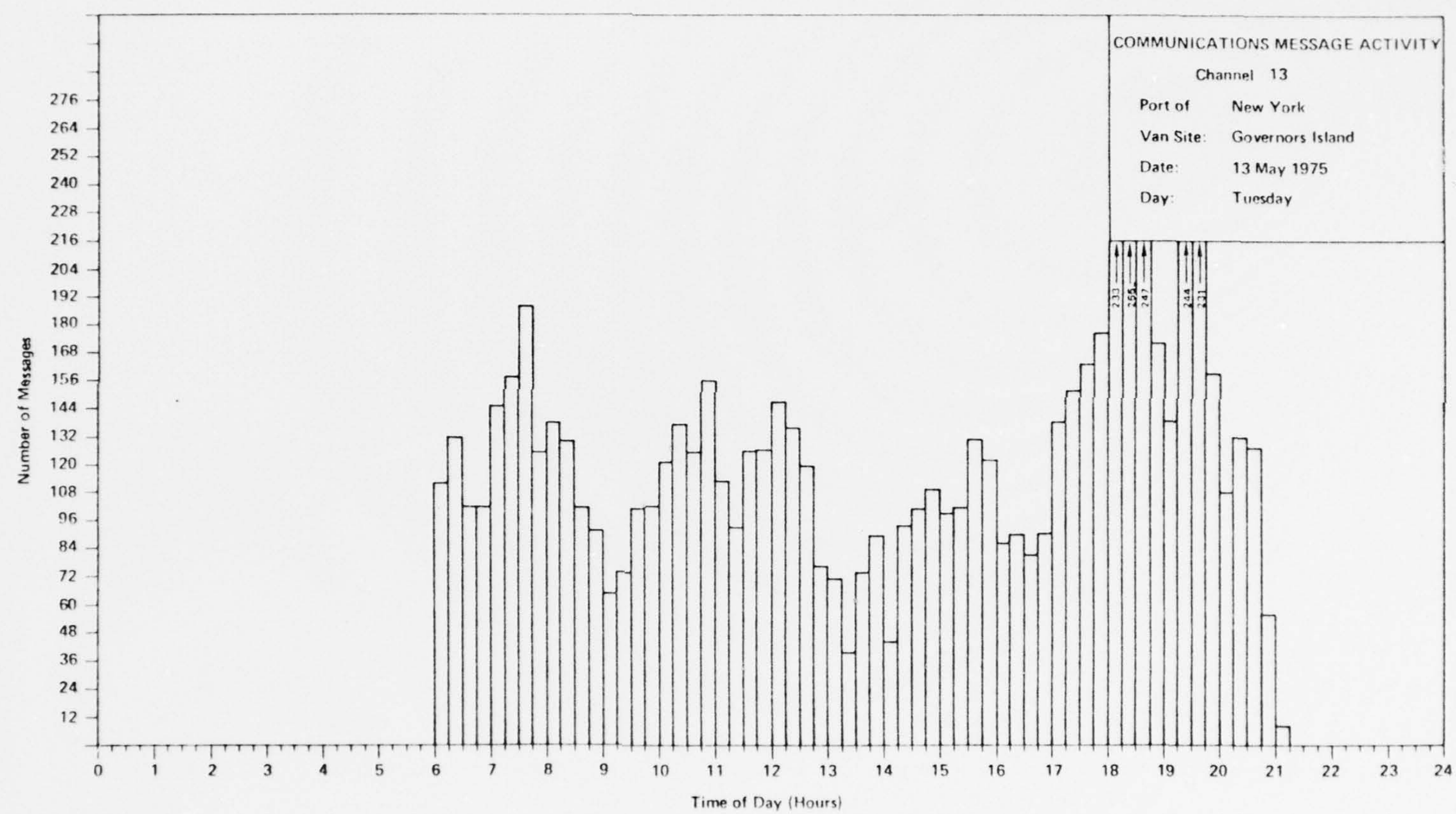


Figure 2.21

MESSAGE ACTIVITY HISTOGRAM, FINAL FORM

2.6 CHANNEL EFFICIENCY

2.6.1 Definition of Terms

Channel efficiency is the percentage of valid messages to total messages per sample period. For hannel 13, valid messages are those judged to be conforming to the Bridge-to-Bridge Radiotelephone Act, which allows for the use of Channel 13 for purposes of navigation.

2.6.2 Data Extraction

- Equipment Set Up

  1) Connect translator to the Channel 16 (left) output jack.

  2) Place tape in tape player and with channel 16 (left) channel at maximum level, run fast forward and/or fast reverse as necessary to get tape to time of first sample interval.

- Procedure

  1) Listen to Channel 13 on maximum volume, keeping the volume on Channel 16 turned up just enough so the translator can decode the time code.

  2) Record the number of valid bridge-to-bridge messages and "other" messages transmitted on Channel 13. "Other" messages are inaudible and invalid transmissions. An example of the data recording form is given in Figure 2.22.

Site [illegible]
Day 5/13/75
Time

Tape No I
Page No. I

Time	Message Valid	Message Other	Total Message	Eff. %				
0602-0617			125	104/125 = 83.2%	83%			
0704-0719	120	16	136	120/136 88.24%	88%			
0807-0822	99	30	129	99/129 76.74%	77%			
0907-0922	71	16	87	71/87 81.61%	82%			
1008-1023	120	22	152	130/152 85.53%	86%			

Figure 2.22

CHANNEL EFFICIENCY RECORDING FORM

3) Listen for a period of 15 minutes.

4) Calculate the efficiency percentage using the following formula:

Number of Valid transmissions/$_{\text{Total number of transmisssions}}$

5) Plot the efficiency percentages calculated.

- Recommendations

1) When time is not available to listen to all the data collected, then listen to one 15 minute interval per hour. Try to have the interval occur around the same time each hour so that comparisons can be made between each hour.

2) Use tapes of the same time period as route identification (for high density), so comparisons can be made between different types of data during the same time period.

2.6.3 Data Display

The channel efficiency data is prepared in much the same way as channel utilization and message activity data. It is first plotted on a pre-printed draft histogram, with time of day as abscissa and efficiency percentage as ordinate. Site and date information is included and then the plot can be readily traced in ink onto the final pre-printed efficiency histogram. Examples of the draft and final channel efficiency histogram are given in Figures 2.23 and 2.24 .

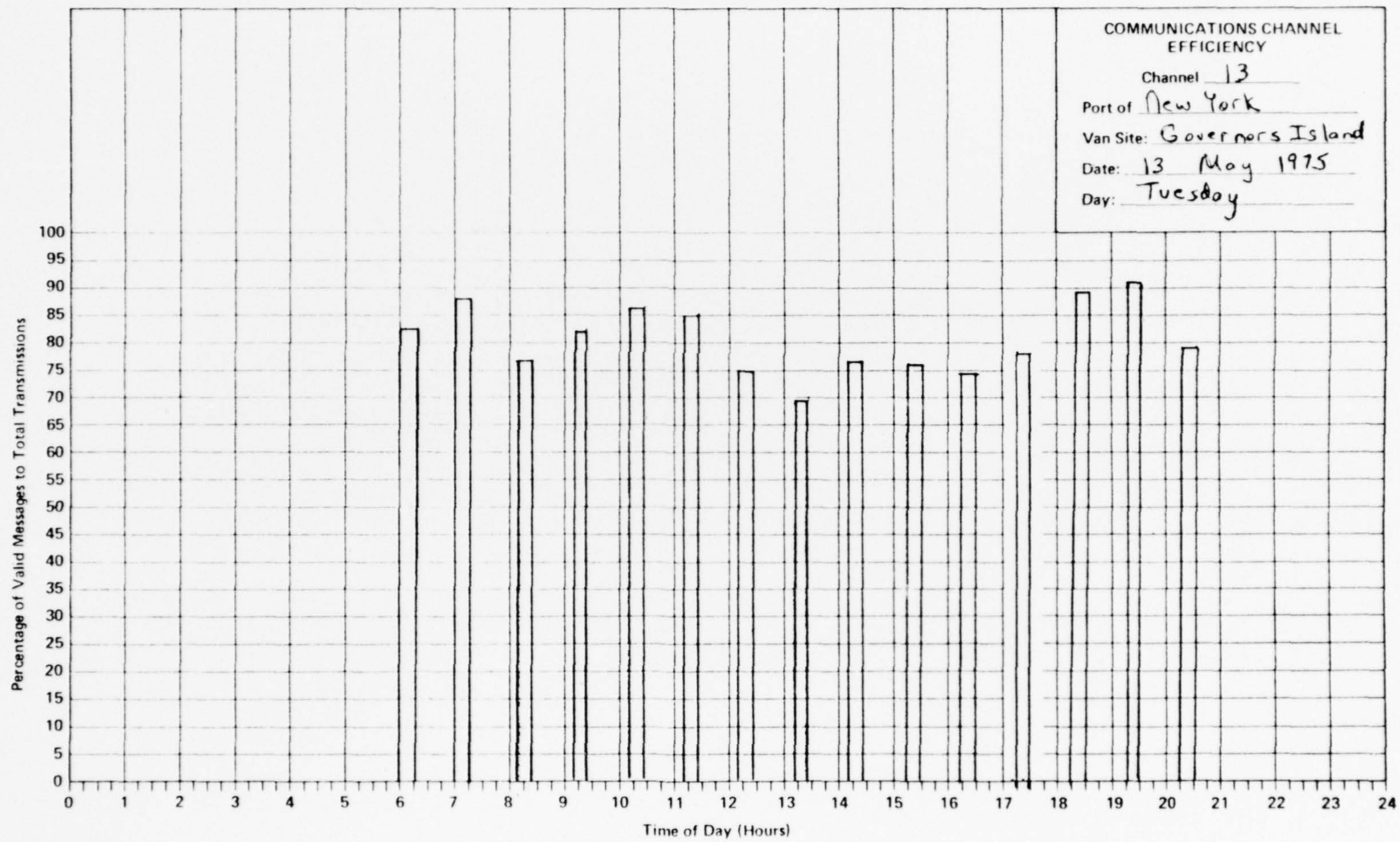


Figure 2.23

CHANNEL EFFICIENCY AND HISTOGRAM,

DRAFT FORM

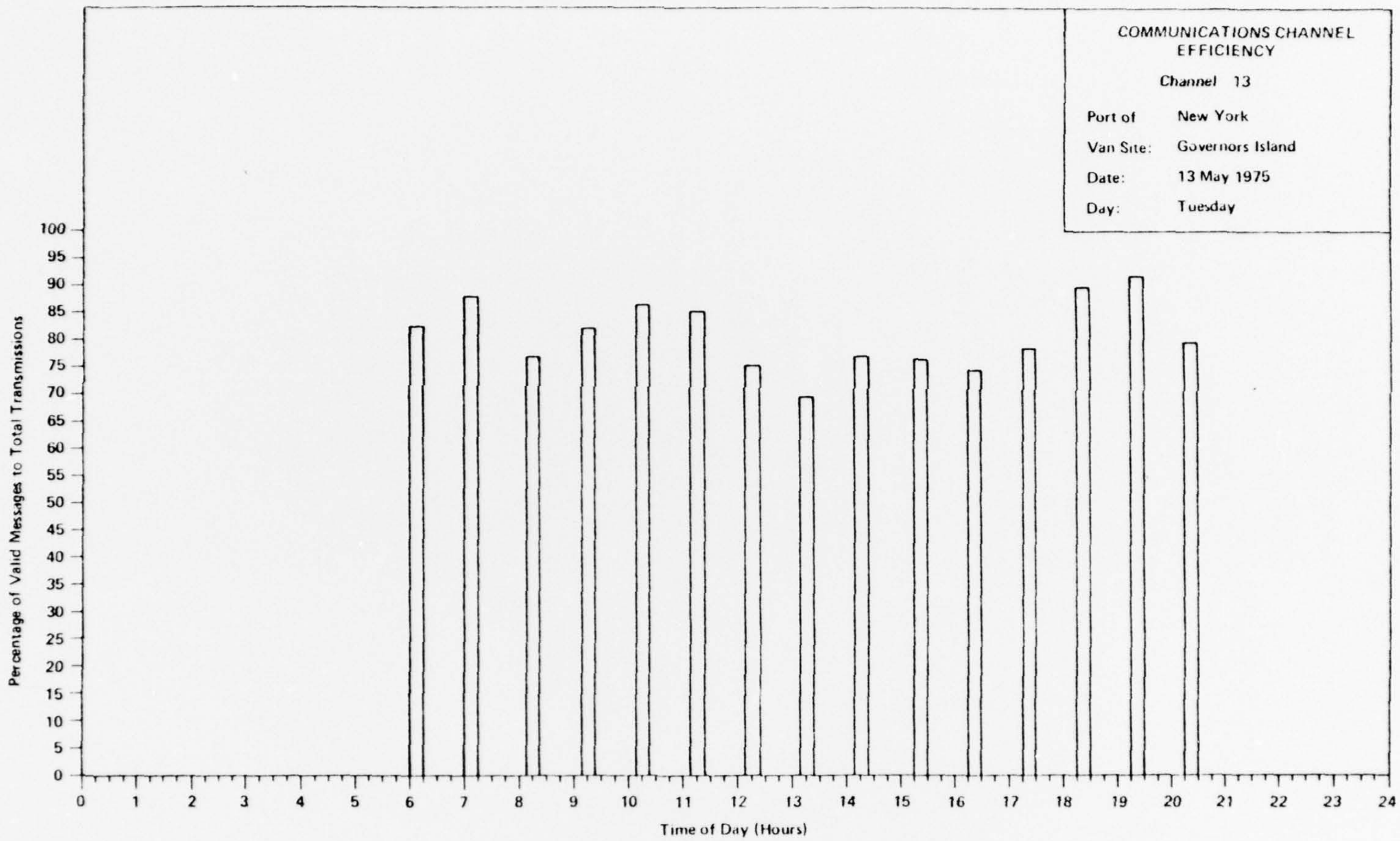


Figure 2.24

CHANNEL EFFICIENCY HISTOGRAM,

FINAL FORM